ATENT COOPERATION TRE, .Y

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark
Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 22 May 2001 (22.05.01)	
International application No. PCT/AU00/01064	**Applicant's or agent's file reference** P15667PCAU
International filing date (day/month/year) 08 September 2000 (08.09.00)	**Priority date** (day/month/year) 08 September 1999 (08.09.99)
Applicant HOUSTON, Rodney, Alexander et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

13 March 2001 (13.03.01)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Charlotte ENGER
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

Form PCT/IB/331 (July 1992)

AU0001064

CLAIMS:

1. A method of treating NOx emissions in the exhaust gas of an internal combustion engine having catalyst means including at least a first catalyst converter capable of treating NOx, the method including operating the engine in a first mode to promote a first set of conditions and in a second mode to promote a second set of conditions, wherein the first mode of operation includes operating the engine with a lean air-fuel ratio, and the second mode of operation includes operating the engine with a stoichiometric air-fuel ratio, the method further including controlling the operation of the engine during the first mode so as to promote a selective catalyst NOx reduction process at the first catalytic converter.

2. A method according to claim 1, wherein the first set of conditions include exhaust gases at a relatively low exhaust gas temperature.

3. A method according to claim 2, wherein the exhaust gas temperature is in the range of 200 to 400 degrees Celsius.

4. A method according to [any one of claim 1] claims 1 to [3], wherein the second set of conditions include exhaust gases at a relatively high exhaust gas temperature.

5. A method according to claim 4, wherein the exhaust gas temperature is greater than 200 degrees Celsius.

6. A method according to claim 5, wherein the exhaust gas temperature is greater than 400 degrees Celsius.

7. A method according to [any one of claim 2] claims 2 to [6], including measuring the exhaust gas temperature at the first catalyst converter.

8. A method according to claim 1, including controlling the temperature of the exhaust gas temperature of the engine by appropriate operation of the engine to ensure effective operation of the first catalyst converter under the first mode of operation.

9. A method according to claim 8, including controlling the exhaust gas temperature to be in the range of 200 to 400 degrees Celsius.

10. A method according to claim 1[8 or 9,] including controlling the temperature of the exhaust gas temperature of the engine by appropriate operation of the engine to ensure effective operation of the first catalyst converter under the second mode of operation.

11. A method according to claim 10, including controlling the exhaust gas temperature to be greater than approximately 400 degrees Celsius.

12. A method according to [any one (claim 1) of the preceding claims,] wherein the operation of the engine is controlled during the first mode so as to generate the exhaust gas emissions having characteristics that can support acceptable levels of NOx conversion within the first catalyst converter.

13. A method according to [any one (claim 1) of the preceding claims,] wherein the first catalyst converter includes a combination of Pt, Rh and Ba elements.

14. A method according to [any one (claim 1) of claims 1 to 13,] wherein the first catalyst converter includes a combination of Pd, Rh and Ba elements.

15. A method according to claim 13, wherein the proportion of Pt is greater than for a typical three way catalyst.

16. A method according to claim 14, wherein the ratio of Pt to Rh is 10:1.

17. A method according to claim 13, [15 or 16,] wherein the proportion of Ba in the first catalyst converter is relatively low as compared to the proportions of Pt and Rh.

18. A method according to [any one of claim 1 the preceding claims] including controlling the operation of the engine during the second mode so as to promote high NOx conversion efficiency levels within the first catalytic converter.

19. A method according to claim 18, including operating the engine in the first mode when the sensed temperature is between 200 to 400 degrees Celsius, and operating the engine in the second mode when the sensed temperature is greater than 400 degrees Celsius.

20. A method according to [any one of claim 1 the preceding claims,] wherein the first catalyst converter is provided in the exhaust system at a position sufficiently downstream of the engine such that there is some cooling of the exhaust gas prior to the exhaust gas entering the first catalyst converter.

21. A method according to claim 20, wherein the catalyst means includes a second catalyst converter provided in a close coupled configuration with the engine for the purpose of oxidising hydrocarbon and carbon monoxide emissions in the exhaust gas.

22. A method according to [any one of claim 1 the preceding claims] wherein the first catalyst converter is a three way catalyst.

23. A method according to [any one of claim 1 the preceding claims,] wherein the engine is directed injected.

24. A method according to claim 23, wherein the engine has a two fluid fuel injection system.

25. An engine exhaust system for treating NOx emissions in the exhaust gas of an internal combustion engine, including catalyst means having at least a first catalyst converter capable of treating NOx, wherein the engine exhaust system is adapted to at least selectively reduce a portion of the NOx emissions when the

engine is operated in a first mode and a first set of conditions are promoted, and the first mode of operation includes operating the engine with a lean air-fuel ratio.

26. An engine exhaust system as claimed in claim 25 wherein the engine exhaust system is adapted to reduce NOx emissions with high conversion efficiency when the engine is operated in a second mode of operation and a second set of conditions are promoted wherein said second mode is a substantially stoichiometric air fuel ratio.

27. An engine exhaust system as claimed in claim 25 or 26 for use with direct injection engine whereby said first mode of operation is promoted.

28. An engine as claimed in claim 27 wherein said direct injection engine utilises an air assisted direct injection fuel system.

29. An engine exhaust system according to any one of claims 25 to 28 wherein the first catalyst converter includes a combination of Pt, Rh and Ba elements.

30. An engine operating system according to any one of claims 25 to 28 wherein the first catalyst converter includes a combination of Pd, Rh and Ba elements.

31. An engine exhaust system according to claim 29, wherein the proportion of Pt is greater than for a typical three way catalyst.

32. An engine exhaust system according to claim 31, wherein the ratio of Pt to Rh is 10:1.

33. An engine exhaust system according to claim 29, 30 or 31, wherein the proportion of Ba in the first catalyst converter is relatively low as compared to the proportions of Pt and Rh.

34. An engine exhaust system according to [any one of claims 25 to 32,] including a temperature sensing device provided in the exhaust system of the engine for measuring the exhaust gas temperature.

35. An engine exhaust system according to claim 34, wherein the temperature sensing device is located at the first catalyst converter.

36. An engine exhaust system according to claim 34 [or 35,] wherein the engine is operated in the first mode when the sensed temperature is between 200 to 400 degrees Celsius, and the engine is operated in the second mode when the sensed temperature is greater than 400 degrees Celsius.

37. An engine exhaust system according to [any one of claims 25 to 36,] wherein the first catalyst converter is provided in the exhaust system at a position sufficiently downstream of the engine such that there is some cooling of the exhaust gas prior to the exhaust gas entering the first catalyst converter.

38. A method according to claim 37, wherein the catalyst means includes a second catalyst converter provided in a close coupled configuration with the engine for the purpose of oxidising hydrocarbon and carbon monoxide emissions in the exhaust gas.

39. A method according to [any one of claims 25 to 38,] wherein the first catalyst converter is a three way catalyst.

40. An electronic control unit for controlling an internal combustion engine having catalyst means including at least a first catalyst converter capable of treating NOx, the electronic control unit operating the engine in a first mode to promote a first set of conditions and in a second mode to promote a second set of conditions, wherein the first mode of operation includes operating the engine with a lean air-fuel ratio, and the second mode of operation includes operating the engine with a stoichiometric air-fuel ratio to thereby treat NOx emissions in the exhaust gas of the engine, the electronic control unit further operating the engine

during the first mode so as to promote a selective catalyst NOx reduction process at the first catalytic converter.

41. An internal combustion engine for use with an exhaust treatment system having reversible NOx adsorbent capability, said engine having a fuel injection system which facilitates operation of said engine with a plurality of air fuel ratios in a range between lean and rich and said engine having an electronic controller for controlling operation of said engine and for selecting between said air fuel ratios wherein said selection is not directly dependent on the amount of NOx stored or calculated to be stored in said exhaust treatment system, and wherein exhaust emissions generated by said engine at a substantially stoichiometric air fuel ratio and transmitted to said exhaust treatment system operate to purge NOx stored in said exhaust treatment system over a Euro 3 drive cycle.

42. An internal combustion engine as claimed in claim 41 wherein said selection between said air fuel ratios by said electronic controller is independent of the amount of NOx stored or calculated to be stored in said exhaust treatment system.

43. An internal combustion engine as claimed in claim 41 [or claim 42] wherein at least some of the NOx stored in said exhaust treatment system is purged therefrom in response to operation of the engine with a substantially stoichiometric or rich air fuel ratio.

44. An internal combustion engine as claimed in claim 41 [or claim 42] wherein at least some of the NOx stored in said exhaust treatment system is purged therefrom in response to operation of the engine with a stoichiometric air fuel ratio.

45. An internal combustion engine as claimed in [any one of claims 41 to 44] wherein said selection is at least in part dependent on engine load demand.

46. An internal combustion engine as claimed in [any one of claims 41 to 43] wherein exhaust emissions generated by said engine at a substantially stoichiometric or rich air fuel ratio and transmitted to said exhaust treatment system operate to purge NOx stored in said exhaust treatment system.

47. An internal combustion engine as claimed in [any one of claims 41 to 43] wherein exhaust emissions generated by said engine at a stoichiometric air fuel ratio and transmitted to said exhaust treatment system operate to purge NOx stored in said exhaust treatment system.

48. An internal combustion engine as claimed in [any one of claim 46] wherein exhaust emissions generated by said engine at a substantially stoichiometric air fuel ratio and transmitted to said exhaust treatment system operate to purge NOx stored in said exhaust treatment system over a Euro 4 drive cycle.

49. An internal combustion engine as claimed in [any one of claims 41 to 48] wherein the amount of NOx emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than four times the Euro III requirement.

50. An internal combustion engine as claimed in claim 49 wherein the amount of NOx emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than three times the Euro III requirement.

51. An internal combustion engine as claimed in [any one of claims 41 to 50] wherein the amount of carbon monoxide emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than three times the Euro III requirement.

52. An internal combustion engine as claimed in [any one of claims 41 to 51] wherein the amount of hydrocarbons emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than ten times the Euro III requirement.

53. An internal combustion engine as claimed in [any one of claim 41] claims 41 to 52 wherein said engine is a direct injection gasoline engine.

54. An internal combustion engine as claimed in [any one of claim 41] claims 41 to 53 wherein said engine is a dual fluid direct injection engine.

55. An internal combustion engine and exhaust treatment system for a vehicle, said exhaust treatment system having reversible NOx adsorbent capability, said engine having a fuel injection system which facilitates operation of said engine with a plurality of air fuel ratios in a range between lean and rich and said engine having an electronic controller for controlling operation of said engine and for selecting between said air fuel ratios wherein the amount of NOx emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than four times the Euro III requirement whereby said exhaust treatment system has emissions of NOx, carbon monoxide and hydrocarbons less than said Euro III requirement over said Euro III drive cycle.

56. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 55 wherein said selection of air fuel ratio by said electronic controller is independent of the amount of NOx stored in said exhaust treatment system.

57. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 55 wherein exhaust emissions generated by said engine at a substantially stoichiometric air fuel ratio and transmitted to said exhaust treatment system operate to purge NOx stored in said exhaust treatment system during said Euro III drive cycle.

58. An internal combustion engine and exhaust treatment system for a vehicle as claimed in [any one of claim 55] claims 55 to 57 wherein the amount of hydrocarbons emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than ten times the Euro III requirement.

59. An internal combustion engine and exhaust treatment system for a vehicle as claimed in [any one of claims 55 to 58] wherein the amount of carbon monoxide emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than three times the Euro III requirement.

60. An internal combustion engine and exhaust treatment system as claimed in [any one of claims 55 to 59] wherein selection of a substantially stoichiometric air fuel ratio is dependent at least in part on driver demand.

61. An internal combustion engine and exhaust treatment system for a vehicle as claimed in [any one of claims 55 to 60] wherein for substantially all of the lean air fuel ratios, said electronic controller operates said engine with EGR levels of 25% by mass or greater.

62. An internal combustion engine and exhaust treatment system for a vehicle as claimed in [any one of claims 55 to 61] wherein said engine is a direct injection engine.

63. An internal combustion engine and exhaust treatment system for a vehicle as claimed in [any one of claims 55 to 62] wherein said engine is a duel fluid direct injection engine.

64. An internal combustion engine for use with an exhaust treatment system having reversible NOx adsorbent capability, said engine having a fuel injection system which facilitates operation of said engine with a plurality of air fuel ratios in a range between lean and substantially stoichiometric and said engine having an electronic controller for controlling operation of said engine and for selecting said substantially stoichiometric air fuel ratio to purge NOx stored in said exhaust treatment system, wherein exhaust emissions generated by said engine when operated with a substantially stoichiometric air fuel ratio and transmitted to said exhaust treatment system operate to purge NOx stored in said exhaust treatment system during a Euro III drive cycle.

65. An internal combustion engine as claimed claim 64 wherein exhaust emissions generated by said engine at a substantially stoichiometric air fuel ratio and transmitted to said exhaust treatment system operate to purge NOx stored in said exhaust treatment system during a Euro IV drive cycle.

66. An internal combustion engine as claimed in claim 64 [or 65] wherein the selection of said substantially stoichiometric air fuel ratio is effected independent of the amount of NOx stored or calculated to be stored in said exhaust treatment system.

67. An internal combustion engine as claimed in claim 64 [to 66] wherein the amount of NOx emitted by said engine to said exhaust treatment system during said Euro III drive cycle are no more than four times the Euro III requirement.

68. An internal combustion engine as claimed in [any one of claims 64 to 66] wherein the amount of NOx emitted by said engine to said exhaust treatment system during said Euro III drive cycle are no more than three times the Euro III requirement.

69. An internal combustion engine as claimed in [any one of claims 64 to 68] wherein the amount of carbon monoxide emitted by said engine to said exhaust treatment system during said Euro III drive cycle is no more than three times the Euro III requirement.

70. An internal combustion engine as claimed in [any one of claims 64 to 69] wherein the amount of hydrocarbons emitted by said engine to said exhaust treatment system during said Euro III drive cycle is no more than ten times the Euro III requirement.

71. An internal combustion engine as claimed in [any one of claims 64 to 70] wherein for substantially all of the lean air fuel ratios, said engine operates with EGR levels of 25% by mass or greater.

72. An internal combustion engine as claimed in [any one of claims 64 to 71] wherein said electronic controller selects said stoichiometric air fuel ratio at least as a cumulative measure of emissions transmitted to the exhaust treatment system.

73. An internal combustion engine as claimed in claim 72 wherein said cumulative measure is determined from engine operating conditions over a predetermined period of time.

74. An internal combustion engine as claimed in claim 73 wherein said operating conditions is at least one of engine speed and / or engine load.

75. An internal combustion engine as claimed in [any one of claims 73 or 74] wherein said predetermined period of time is elapsed time since said engine operated with a stoichiometric air fuel ratio.

76. An internal combustion engine as claimed in claim 75 wherein said predetermined period of time is elapsed time since said engine operate with a stoichiometric air fuel ratio for a period sufficient to substantially purge said catalyst of stored NOx.

77. An internal combustion engine as claimed in [any one of claim 72 to 76] wherein said cumulative measure is an estimate based on emission levels emitted at each selected air fuel ratio.

78. An internal combustion engine as claimed in [any one of claims 72 to 77] wherein said cumulative measure is based on the amount of time said engine was operated at each selected air fuel ratio.

79. An internal combustion engine as claimed in [any one of claims 72 to 78] wherein said stoichiometric air fuel ratio is selected for a period sufficient to regenerate said exhaust treatment system from stored NOx and wherein

subsequent to said period sufficient to regenerate said exhaust treatment system said electronic controller selects an air fuel ratio dependent on prevailing engine conditions.

80. An internal combustion engine as claimed in [any one of claims 64 to 71] wherein said electronic controller selects said stoichiometric air fuel ratio in response to a sensing means operatively arranged with respect to the exhaust treatment system which is able to provide an indication on the amount of NOx stored therein.

81. An internal combustion engine as claimed in claim 80 wherein said electronic controller only selects said stoichiometric air fuel ratio in response to a signal from said sensing means that purging of NOx from the exhaust treatment system is required.

82. An internal combustion engine as claimed in [claims 80 or 81] wherein said selection of said stoichiometric air fuel ratio by the electronic controller to effect purging of NOx from the exhaust treatment system is also dependent on the volume of a catalyst in the exhaust treatment system.

83. An internal combustion engine as claimed in [any one of claims 64 to 82] wherein said engine is a direct injection engine.

84. An internal combustion engine as claimed in [any one of claims 64 to 83] wherein said engine is a dual fluid direct injection engine.

85. An internal combustion engine and exhaust treatment system for use in a vehicle, said exhaust treatment system comprising at least one catalyst having three way conversion capability and NOx storage capability, wherein the amount of NOx emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than four times the Euro III requirement whereby said exhaust treatment system has emissions of NOx, carbon monoxide and hydrocarbons less than said Euro III requirement over said Euro III drive cycle,

and the volume of the catalyst is less than 150% of the swept volume of said engine.

86. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 85 wherein said catalyst has substantially two zones, a first of which has said three way conversion capability and a second of which has at least said NOx storage capability

87. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 86 wherein said second zone of said catalyst has three way conversion capability in addition to said NOx storage capability.

88. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 86 wherein said first zone is located so as to received exhaust emissions from said engine before said second zone.

89. An internal combustion engine and exhaust treatment system for a vehicle as claimed in [any one of claims 85 to 88] wherein said exhaust treatment system has a single canister for locating said at least one catalyst, said canister located remotely from an exhaust port of said engine and not within an engine compartment in which the engine is installed.

90. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 89 wherein single canister is located in an underbody location and has dimensions of less than 150% of the swept volume of the engine.

91. An internal combustion engine and exhaust treatment system for a vehicle as claimed in [any one of claims 85 to 90] wherein exhaust emissions generated by said engine when operated with a substantially stoichiometric air fuel ratio operate to purge NOx stored in said exhaust treatment system during said Euro III drive cycle.

92. An internal combustion engine and exhaust treatment system for a vehicle as claimed in [any one of claim 85 claims 85 to 91] wherein the amount of carbon monoxide emitted by said engine to said exhaust treatment system over said Euro III drive cycle is no more than three times the Euro III requirement.

93. An internal combustion engine and exhaust treatment system for a vehicle as claimed in [any one of claim 85 claims 85 to 92] wherein the amount of hydrocarbons emitted by said engine to said exhaust treatment system over said Euro III drive cycle is no more than ten times the Euro III requirement.

94. An internal combustion engine and exhaust treatment system for a vehicle as claimed in [any one of claim 85 claims 85 to 93] wherein the amount of NOx emitted by said engine to said exhaust treatment system over said Euro III drive cycle is no more than three times the Euro III requirement.

95. An internal combustion engine and exhaust treatment system for a vehicle as claimed in [any one of claim 85 claims 85 to 94] wherein for substantially all of the lean air fuel ratios, said engine operates with EGR levels of 25% by mass or greater.

96. An internal combustion engine and exhaust treatment system for a vehicle as claimed in [any one of claim 85 claims 85 to 95] wherein in operation said catalyst is heated by a light off strategy.

97. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 96 wherein said light off strategy comprises late combustion of fuel whilst an exhaust port of said engine is open whereby said catalyst receives exhaust emissions of an elevated temperature.

98. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 97 wherein late combustion of fuel comprises a quantity of fuel in addition to a quantity required for operation of said engine independent of said light off strategy.

99. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 85 to 98 wherein said engine is a direct injection engine.

100. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 85 to 99 wherein said engine is a dual fluid direct injection engine.

PATENT COOPERATION TREATY

From the:
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

WATERMARK PATENT & TRADEMARK ATTORNEYS
Level 21 Allendale Square
77 St Georges Terrace
PERTH W.A. 6000

PCT

NOTIFICATION OF TRANSMITTAL OF INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

	Date of mailing *day/month/year* 13 NOV 2001
Applicant's or agent's file reference P15667PCAU	**IMPORTANT NOTIFICATION**

International Application No.	International Filing Date	Priority Date
PCT/AU00/01064	8 September 2000	8 September 1999

Applicant
ORBITAL ENGINE COMPANY (AUSTRALIA) PTY LIMITED et al

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translations to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices)(Article 39(1))(see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	KURT TOBLER Telephone No. (02) 6283 2469

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P15667PCAU	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).
International Application No. PCT/AU00/01064	International Filing Date *(day/month/year)* 8 September 2000	Priority Date *(day/month/year)* 8 September 1999

International Patent Classification (IPC) or national classification and IPC

Int. Cl.[7] F02D 41/34, 43/04, F02M 69/42, F02B 75/10, F01N 3/18, 3/20

Applicant

ORBITAL ENGINE COMPANY (AUSTRALIA) PTY LIMITED et al

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   [X] This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 34 sheet(s).

3. This report contains indications relating to the following items:

I	[X]	Basis of the report
II	[ ]	Priority
III	[ ]	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	[X]	Lack of unity of invention
V	[X]	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	[X]	Certain documents cited
VII	[ ]	Certain defects in the international application
VIII	[X]	Certain observations on the international application

Date of submission of the demand	Date of completion of the report
13 March 2001	29 October 2001 13 NOV 2001
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer **KURT TOBLER** Telephone No. (02) 6283 2469

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/AU00/01064

I. Basis of the report

1. With regard to the **elements** of the international application:*

- [ ] the international application as originally filed.
- [X] the description, pages , as originally filed,
  pages , filed with the demand,
  pages **1-19**, received on **17 October 2001.**
- [X] the claims, pages , as originally filed,
  pages , as amended (together with any statement) under Article 19,
  pages , filed with the demand,
  pages **20-34**, received on **17 October 2001.**
- [X] the drawings, pages **1-5**, as originally filed,
  pages , filed with the demand,
  pages , received on with the letter of
- [ ] the sequence listing part of the description:
  pages , as originally filed
  pages , filed with the demand
  pages , received on with the letter of

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language which is:

- [ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- [ ] the language of publication of the international application (under Rule 48.3(b)).
- [ ] the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- [ ] contained in the international application in written form.
- [ ] filed together with the international application in computer readable form.
- [ ] furnished subsequently to this Authority in written form.
- [ ] furnished subsequently to this Authority in computer readable form.
- [ ] The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- [ ] The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

4. [ ] The amendments have resulted in the cancellation of:
   - [ ] the description, pages
   - [ ] the claims, Nos.
   - [ ] the drawings, sheets/fig.

5. [ ] This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report*

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

☐ restricted the claims.

☐ paid additional fees.

☐ paid additional fees under protest.

☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied with and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

☐ complied with.

☒ not complied with for the following reasons:

The international application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept. In coming to this conclusion the International Searching Authority has found that there are different inventions as follows:

1. Claims 1- 84 relate to exhaust gas treatment for an engine operating at various air-fuel ratios. It is considered that a exhaust gas treatment for an engine operating at various ratios comprises a first " special technical feature".

2. Claims 85- 100 are directed to an engine with exhaust gas treatment with NOx storage capacity and catalyst volume less than 150% of the engine swept volume. It is considered that a catalyst volume less than 150% of the engine swept volume comprises a second " special technical feature ".

Since the above mentioned groups of claims do not share any of the technical features identified, a " technical relationship" between the inventions, as defined in PCT rule 13.2 does not exist. Accordingly the international application does not relate to one invention or to a single inventive concept.

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

☒ all parts.

☐ the parts relating to claims Nos.

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-100	YES
	Claims		NO
Inventive step (IS)	Claims	1-100	YES
	Claims		NO
Industrial applicability (IA)	Claims	1-100	YES
	Claims		NO

2. Citations and explanations (Rule 70.7)

The claims as proposed to be amended are novel in the light of the art cited in the International Search Report. The claims (1-84) use of controlling the operation of the engine during a lean air-fuel ratio mode so as to promote a selective NOx reduction process at a first catalytic converter is not taught by the cited art and is therefore novel. Claims 85-100 disclose an engine with a catalyst volume less than 150% of the swept volume of the engine, and is also novel in the light of the cited art.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/AU00/01064

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

Application No. Patent No.	Publication date *(day/month/year)*	Filing date *(day/month/year)*	Priority date (valid claim) *(day/month/year)*
P,X JP 20000 87788 A	28 March 2000	9 September 1998	

This document implicitly or explicitly discloses the features of claims 1-12, 21, 23-26, 32-45, 52, 53, 63, 66, 80-84.

2. Non-written disclosures (Rule 70.9)

Kind of non-written disclosure	Date of non-written disclosure *(day/month/year)*	Date of written disclosure referring to non-written disclosure *(day/month/year)*

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

The invention defined by claims 1, 26, 38, 39, 54 and 63 is not clear due to the various permutations/combinations of integers defined.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P15667PCAU	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).
International Application No. **PCT/AU00/01064**	International Filing Date *(day/month/year)* 8 September 2000	Priority Date *(day/month/year)* 8 September 1999

International Patent Classification (IPC) or national classification and IPC

Int. Cl. [7] F02D 41/34, 43/04, F02M 69/42, F02B 75/10, F01N 3/18, 3/20

Applicant

ORBITAL ENGINE COMPANY (AUSTRALIA) PTY LIMITED et al

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   [X] This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of **34** sheet(s).

3. This report contains indications relating to the following items:

I	[X]	Basis of the report
II	[ ]	Priority
III	[ ]	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	[X]	Lack of unity of invention
V	[X]	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	[X]	Certain documents cited
VII	[ ]	Certain defects in the international application
VIII	[X]	Certain observations on the international application

Date of submission of the demand 13 March 2001	Date of completion of the report 29 October 2001 13 NOV 2001
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer **KURT TOBLER** Telephone No. (02) 6283 2469

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/AU00/01064

I. Basis of the report

1. With regard to the elements of the international application:*

- [ ] the international application as originally filed.
- [X] the description, pages , as originally filed,
  pages , filed with the demand,
  pages **1-19**, received on **17 October 2001.**
- [X] the claims, pages , as originally filed,
  pages , as amended (together with any statement) under Article 19,
  pages , filed with the demand,
  pages **20-34**, received on **17 October 2001.**
- [X] the drawings, pages **1-5**, as originally filed,
  pages , filed with the demand,
  pages , received on with the letter of
- [ ] the sequence listing part of the description:
  pages , as originally filed
  pages , filed with the demand
  pages , received on with the letter of

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language which is:

- [ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- [ ] the language of publication of the international application (under Rule 48.3(b)).
- [ ] the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- [ ] contained in the international application in written form.
- [ ] filed together with the international application in computer readable form.
- [ ] furnished subsequently to this Authority in written form.
- [ ] furnished subsequently to this Authority in computer readable form.
- [ ] The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- [ ] The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

4. [ ] The amendments have resulted in the cancellation of:
   - [ ] the description, pages
   - [ ] the claims, Nos.
   - [ ] the drawings, sheets/fig.

5. [ ] This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report*

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/AU00/01064

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

☐ restricted the claims.

☐ paid additional fees.

☐ paid additional fees under protest.

☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied with and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

☐ complied with.

☒ not complied with for the following reasons:

The international application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept. In coming to this conclusion the International Searching Authority has found that there are different inventions as follows:

1. Claims 1- 84 relate to exhaust gas treatment for an engine operating at various air-fuel ratios. It is considered that a exhaust gas treatment for an engine operating at various ratios comprises a first " special technical feature".

2. Claims 85- 100 are directed to an engine with exhaust gas treatment with NOx storage capacity and catalyst volume less than 150% of the engine swept volume. It is considered that a catalyst volume less than 150% of the engine swept volume comprises a second " special technical feature ".

Since the above mentioned groups of claims do not share any of the technical features identified, a " technical relationship" between the inventions, as defined in PCT rule 13.2 does not exist. Accordingly the international application does not relate to one invention or to a single inventive concept.

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

☒ all parts.

☐ the parts relating to claims Nos.

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	**1-100**	**YES**
	Claims		**NO**
Inventive step (IS)	Claims	**1-100**	**YES**
	Claims		**NO**
Industrial applicability (IA)	Claims	**1-100**	**YES**
	Claims		**NO**

2. Citations and explanations (Rule 70.7)

The claims as proposed to be amended are novel in the light of the art cited in the International Search Report. The claims (1-84) use of controlling the operation of the engine during a lean air-fuel ratio mode so as to promote a selective NOx reduction process at a first catalytic converter is not taught by the cited art and is therefore novel. Claims 85-100 disclose an engine with a catalyst volume less than 150% of the swept volume of the engine, and is also novel in the light of the cited art.

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

Application No. Patent No.	Publication date *(day/month/year)*	Filing date *(day/month/year)*	Priority date (valid claim) *(day/month/year)*
P,X JP 20000 87788 A	28 March 2000	9 September 1998	

This document implicitly or explicitly discloses the features of claims 1-12, 21, 23-26, 32-45, 52, 53, 63, 66, 80-84.

2. Non-written disclosures (Rule 70.9)

Kind of non-written disclosure	Date of non-written disclosure *(day/month/year)*	Date of written disclosure referring to non-written disclosure *(day/month/year)*

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

The invention defined by claims 1, 26, 38, 39, 54 and 63 is not clear due to the various permutations/combinations of integers defined.

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

NOTIFICATION OF RECEIPT
OF DEMAND BY COMPETENT INTERNATIONAL
PRELIMINARY EXAMINING AUTHORITY

(PCT Rule 59.3(e) and 61.1(b), first sentence
and Administrative Instructions, Section 601(a))

To: Agent :

WATERMARK PATENT & TRADEMARK
ATTORNEYS
4th Floor, Durack Centre
263 Adelaide Terrace
PERTH W.A. 6000

Date of mailing *(day/month/year)*	16 MAR 2001 (16/3/01)
Applicant's or agent's file reference	**IMPORTANT NOTIFICATION**
P15667PCAU	

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/AU00/01064	8 SEP 2000 (8/9/00)	8 SEP 1999 (8/9/99)

Applicant
Orbital Engine Company (Australia) Pty Limited (et al.)

1. The applicant is hereby **notified** that this International Preliminary Examining Authority considers the following date as the date of receipt of the demand for international preliminary examination of the international application:

13 MAR 2001 (13/3/01)

2. That date of receipt is:

☒ the actual date of receipt of the demand by this Authority (Rule 61.1(b)).

☐ the actual date of receipt of the demand on behalf of this Authority (Rule 59.3(e)).

☐ the date on which this Authority has, in response to the Invitation to correct defects in the demand (Form PCT/IPEA/404), received the required corrections.

3. ☐ **Attention:** That date of receipt is **AFTER** the expiration of 19 months from the priority date. Consequently, the elections(s) made in the demand does (do) not have the effect of postponing the entry into the national phase until 30 months from the priority date (or later in some Offices) (Article 39(1)). Therefore, the acts for entry into the national phase must be performed within 20 months from the priority date (or later in some Offices) (Article 22). For details, see the *PCT Applicant's Guide, Volume II.*

☐ *(If applicable)* This notification confirms the information given by telephone, facsimile transmission or in person on:

4. Only where paragraph 3 applies, a copy of this notification has been sent to the International Bureau.

Name and mailing address of the IPEA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE **PO BOX 200, WODEN ACT 2606, AUSTRALIA** E-mail: pct@ipaustralia.gov.au Facsimile No. 02 6285 3929	JOHN COLDWELL Telephone No. 02 6283 7924

The demand must be filed directly with the competent International Preliminary Examining Authority or, if more Authorities are competent, with the one chosen by the applicant. The full name or two-letter code of that Authority may be indicated by the Applicant on the line below:

IPEA/

PCT

CHAPTER II

DEMAND

under Article 31 of the Patent Cooperation Treaty:
The undersigned requests that the international application specified below be the subject of International preliminary examination according to the Patent Cooperation Treaty.

For International Preliminary Examining Authority use only

Identification of IPEA	Date of Receipt of DEMAND

Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION

Applicant's or agent's file reference: P15667PCAU MCQ:KMN

International application No.	International filing date *(day/month/year)*	(Earliest) Priority date *(day/month/year)*
PCT/AU00/01064	08.09.2000 8 September 2000	08.09.1999 8 September 1999

Title of Invention
EXHAUST GAS TREATMENT METHOD AND DEVICE

Box No. II APPLICANT(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country).*

ORBITAL ENGINE COMPANY (AUSTRALIA) PTY LIMITED
1Whipple Street
Balcatta.
Western Australia 6021
Australia

Telephone No.:

Facsimile No.:

Teleprinter No.:

State (i.e. country) of nationality:	State (i.e. country) of residence:
AUSTRALIA	AUSTRALIA

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country).*

HOUSTON, Rodney Alexander,
20 Shorebird Road,
Woodvale.
Western Australia 6026
Australia

State (i.e. country) of nationality:	State (i.e. country) of residence:
AUSTRALIA	AUSTRALIA

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country).*

YANG, Koon Chung,
4 Galen Rise,
Woodvale.
Western Australia 6026
Australia

State *(i.e. country)* of nationality:	State (i.e. country) of residence:
AUSTRALIA	AUSTRALIA

☒ Further applicants are indicated on a continuation sheet.

See Notes to the demand form

International application No.
PCT/AU00/01064

Continuation of Box No. II APPLICANT(S)

If none of the sub-boxes used, this sheet is not to be included in the demand.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country).*

WORTH, David Richard,
21 William Street,
Shenton Park.
Western Australia 6008.
Australia

State *(i.e. country)* of nationality: Australia

State *(i.e. country)* of residence: Australia

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country).*

CATHCART, Geoffrey Paul,
46b Bradley Street,
Yokine.
Western Australia 6060.
Australia.

State *(i.e. country)* of nationality: Australia

State *(i.e. country)* of residence: Australia

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country).*

MOORE, Michael
107 Barker Road,
Subiaco.
Western Australia 6008.
Australia.

State *(i.e. country)* of nationality:

State *(i.e. country)* of residence:

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country).*

State *(i.e. country)* of nationality:

State *(i.e. country)* of residence:

☐ Further applicants are indicated on a continuation sheet.

See Notes to the demand form

International application No.
PCT/AU00/01064

Box No. III AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The following person is ☒ agent ☐ common representative

and ☒ has been appointed earlier and represents the applicant(s) also for international preliminary examination.

☐ is hereby appointed and any earlier appointment of (an) agent(s)/common representative is hereby revoked.

☐ is hereby appointed, specifically for the procedure before the International Preliminary Examining Authority, in addition to the agent(s)/common representative appointed earlier.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country).*

WATERMARK PATENT & TRADEMARK ATTORNEYS
4th Fl, "Durack Centre", 263 Adelaide Terrace,
Perth, WA 6000
Australia

Telephone No.: (08) 9325 1900
Facsimile No.: (08) 9325 4463
Teleprinter No.:

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Box No. IV BASIS FOR INTERNATIONAL PRELIMINATY EXAMINATION

Statement concerning amendments: *

1. This applicant wishes the International Preliminary Examining Authority **to start on the basis of:**
   ☐ the international preliminary examination as originally filed.
   the description ☒ as originally filed
   ☐ as amended under Article 34)
   the claims ☒ as originally filed
   ☐ as amended under Article 19 (together with any accompanying statement)
   ☐ as amended under Article 34
   the drawings ☒ as originally filed
   ☐ as amended under Article 34
2. ☐ The applicant wishes any amendments to the claims under Article 19 to be considered as reversed.
3. ☐ The applicant wishes any amendments to the claims under Article 19 to be considered **to be postponed** until the expiration of 20 months from the priority date unless the International Preliminary Examining Authority receives a copy of any amendments made under Article 19 or a notice from the applicant that he does not wish to make such amendments (Rule 69.1(d)). (This check-box may be marked only where the time limit under Article 19 has not yet expired).

* Where no check-box is marked, international preliminary examination will start on the basis of the international application as originally filed or, where a copy of amendments to the claims under Article 19 and/or amendments of the international application under Article 34 received by the International Preliminary Examining Authority before it has begun to draw up a written opinion or the international preliminary examination report, as so amended.

Language for the purposes of international preliminary examination: ENGLISH

☒ which is the language in which the international application was filed

☐ which is the language of a translation furnished for the purposes of international search.

☐ which is the language of publication of the international application.

☐ which is the language of the translation (to be furnished for the purposes of international preliminary examination.

Box No. V ELECTION OF STATES

The applicant hereby elects all eligible States *(that is, all States which have been designated and which are bound by Chapter II of the PCT)*

excluding the following States which the applicant wishes **not to elect:**

See Notes to the demand form

International application No.
PCT/AU00/01064

Box No. VI CHECK LIST

The demand is accompanied by the following elements, in the language referred to in Box IV, for the purposes of international preliminary examination:			For International Preliminary Examining Authority use only: received	not received
1. translation of international application	:	sheets	☐	☐
2. amendment under Article 34	:	sheets	☐	☐
3. copy (or, where required, translation) of amendments under Article 19	:	sheets	☐	☐
4. copy (or, where required, translation) of statement under Article 19	:	sheets	☐	☐
5. letter	:	sheets	☐	☐
6. other *(specify)*	:	sheets	☐	☐

This demand is also accompanied by the item(s) marked below:

1.	☒	fee calculation sheet	3. ☐	statement explaining lack of signature
2.	☐	separate signed power of attorney	4. ☐	nucleotide and or amino acid sequence listing in computer readable
3.	☐	copy of general power of attorney; reference number, if any:	5. ☐	other *(specify)*

Box No. VII SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the nature of the person signing the capacity in which the person signs (if such capacity is not obvious from reading the demand).

.....
Michael Chin Quan
Registered Patent Attorney of
For and on behalf of Watermark Patent and Trade Mark Attorneys

For International Preliminary Examining Authority use only

1. Date of actual receipt of DEMAND:

2 Adjusted date of receipt of demand due to CORRECTIONS under Rule 60.1(b):

3. ☐ The date of receipt of the demand is AFTER the expiration of 19 months from the priority date and item 4 or 5, below, does not apply ☐ The applicant has been informed accordingly.

4. ☐ The date of receipt of the demand is WITHIN the period of 19 months from the priority date as extended by virtue of Rule 80.5

5. ☐ Although the date of receipt of the demand is after the expiration of 19 months from the priority date, the delay in arrival is EXECUTED pursuant to Rule 82

For International Bureau use only

Demand received from IPEA on:

See Notes to the demand form

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For Receiving Office use only

International Application No.

International Filing Date

Name of Receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* P15667PCAU

Box No. I TITLE OF INVENTION

Exhaust Gas Treatment and Device

Box No. II APPLICANT

Name and Address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.*

ORBITAL ENGINE COMPANY (AUSTRALIA) PTY LIMITED
1 Whipple Street,
Balcatta.
Western Australia 6021.
Australia.

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State *(i.e. country)* of nationality: Australia

State *(i.e. country)* of residence: Australia

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ The States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and Address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.*

HOUSTON, Rodney Alexander,
20 Shorebird Road,
Woodvale.
Western Australia 6026.
Australia

This person is:

☐ applicant only

☒ applicant and inventor

☐ inventor only *(if this check-box is marked, do not fill in below.*

State *(i.e. country)* of nationality: Australia

State *(i.e. country)* of residence: Australia

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ The States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and Address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.*

WATERMARK PATENT & TRADEMARK ATTORNEYS
4th Fl, "Durack Centre", 263 Adelaide Terrace,
Perth, WA 6000
Australia

Telephone No.
(08) 9325 1900

Facsimile No.
(08) 9325 4463

Teleprinter No.

☐ Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Box No. V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked):*

Regional Patent

☒ **AP** **ARIPO Patent:** GH Ghana, GM Gambia, KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SL Sierra Leone, SZ Swaziland, TZ Republic of Tanzania, UG Uganda, ZW Zimbabwe, and any other State which is a contracting State of the Harare Protocol and of the PCT

☒ **EA** **Eurasian Patent:** AM Armenia, AZ Azerbaijan, BY Belarus, KG Kyrgyzstan, KZ Kazakstan, MD Republic of Moldova, RU Russian Federation, TJ Tajikistan, TM Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT

☒ **EP** **European Patent:** AT Austria, BE Belgium, CH and LI Switzerland and Liechtenstein, CY Cyprus, DE Germany, DK Denmark, ES Spain, FI Finland, FR France, GB United Kingdom, GR Greece, IE Ireland, IT Italy, LU Luxembourg, MC Monaco, NL Netherlands, PT Portugal, SE Sweden, any other State which is a Contracting State of the European Patent Convention and of the PCT

☒ **OA** **OAPI Patent:** BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, GW Guinea-Bissau, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line* .....

National Patent *(if other kind of protection or treatment desired, specify on dotted line):*

☒ **AE** United Arab Emirates
☒ **AG** Antigua and Barbuda
☒ **AL** Albania
☒ **AM** Armenia
☒ **AT** Austria
☒ **AU** Australia
☒ **AZ** Azerbaijan
☒ **BA** Bosnia and Herzegovina
☒ **BB** Barbados
☒ **BG** Bulgaria
☒ **BR** Brazil
☒ **BY** Belarus
☒ **BZ** Belize
☒ **CA** Canada
☒ **CH** and **LI** Switzerland and Liechtenstein
☒ **CN** China
☒ **CR** Costa Rica
☒ **CU** Cuba
☒ **CZ** Czech Republic
☒ **DE** Germany
☒ **DK** Denmark
☒ **DM** Dominica
☒ **DZ** Algeria
☒ **EE** Estonia
☒ **ES** Spain
☒ **FI** Finland
☒ **GB** United Kingdom
☒ **GD** Grenada
☒ **GE** Georgia
☒ **GH** Ghana
☒ **GM** Gambia
☒ **HR** Croatia
☒ **HU** Hungary
☒ **ID** Indonesia
☒ **IL** Israel
☒ **IN** India
☒ **IS** Iceland
☒ **JP** Japan
☒ **KE** Kenya
☒ **KG** Kyrgyzstan
☒ **KP** Democratic People's Republic of Korea
☒ **KR** Republic of Korea
☒ **KZ** Kazakstan
☒ **LC** Saint Lucia
☒ **LK** Sri Lanka
☒ **LR** Liberia
☒ **LS** Lesotho
☒ **LT** Lithuania
☒ **LU** Luxembourg
☒ **LV** Latvia
☒ **MA** Morocco
☒ **MD** Republic of Moldova
☒ **MG** Madagascar
☒ **MK** The Former Yugoslav Republic of Macedonia
☒ **MN** Mongolia
☒ **MW** Malawi
☒ **MX** Mexico
☒ **MZ** Mozambique
☒ **NO** Norway
☒ **NZ** New Zealand
☒ **PL** Poland
☒ **PT** Portugal
☒ **RO** Romania
☒ **RU** Russian Federation
☒ **SU** Sudan
☒ **SE** Sweden
☒ **SG** Singapore
☒ **SI** Slovenia
☒ **SK** Slovakia
☒ **SL** Sierra Leone
☒ **TJ** Tajikistan
☒ **TM** Turkmenistan
☒ **TR** Turkey
☒ **TT** Trinidad and Tobago
☒ **UA** Ukraine
☒ **UG** Uganda
☒ **US** United States of America
☒ **UZ** Uzbekistan
☒ **VN** Viet Nam
☒ **YU** Yugoslavia
☒ **ZA** South Africa
☒ **ZW** Zimbabwe

Check-box reserved for designating States which have become party to the PCT after issuance of this sheet:

☐ .....

Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except the designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *Confirmation (including fees) must reach the receiving Office within the 15-month time limit.)*

Continuation of Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

If none of the following sub-boxes is used, this sheet is not to be included in the request

Name and Address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

YANG, Koon Chung,
4 Galen Rise,
Woodvale.
Western Australia 6026.
Australia

This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(if this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: Republic of Korea

State *(i.e. country)* of residence: Australia

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and Address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

WORTH, David Richard,
21 William Street,
Shenton Park.
Western Australia 6008.
Australia.

This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(if this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: United Kingdom

State *(i.e. country)* of residence: Australia

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and Address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

CATHCART, Geoffrey Paul,
46b Bradley Street,
Yokine.
Western Australia 6060
Australia

This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(if this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: Australia

State *(i.e. country)* of residence: Australia

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and Address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

MOORE, Michael,
107 Barker Road,
Subiaco.
Western Australia 6008.
Australia.

This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(if this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: Australia

State *(i.e. country)* of residence: Australia

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further inventors are indicated on a continuation sheet.

Box No. VI PRIORITY CLAIM ☐ Further priority claims are indicated in the Supplemental Box

Filing date of earlier application (day/month/year)	Number of earlier application	Where earlier application is : national application: country	regional application: * regional Office	international application: receiving Office
item (1) (08.09.1999) 8th September, 1999	PQ2722	Australia		Australia
item (2)				
item (3)				

☒ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office for the purposes of the present international application is the receiving Office)* identified above as item(s): item 1

Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii). See Supplemental Box.

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(If two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen, the two-letter code may be used):*

ISA /

Request to use results of earlier search; reference to that search *(if earlier search has been carried out by or requested from the International Searching Authority):*

Date *(date/month/year)* Number Country *(or regional Office)*

Box No. VIII CHECK LIST; LANGUAGE OF FILING

The international application contains the following **number of sheets:**

request	:	4
description excluding sequence listing part)	:	17
claims	:	17
abstract	:	1
drawings	:	5
sequence listing part of description	:	
Total number of sheets	:	44

This international application is accompanied by the item(s) marked below:

1. ☒ fee calculation sheet
2. ☐ separate signed power of attorney
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ priority document(s) identified in Box No. VI as item(s):
6. ☐ translation of internatinal application into (language):
7. ☐ separate indications concerning deposited microorganisms or other biological material
8. ☐ nucleotide and/or amino acid sequence listing in computer readable form
9. ☐ other (specify):

Figure of the drawings which should accompany the abstract:

Language of filing of the international application: ENGLISH

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

Scott J. Martin, Registered Patent Attorney
for and on behalf of WATERMARK PATENT & TRADEMARK ATTORNEYS

For receiving Office use only

1. Date of actual receipt of the purported international application:
2. Drawings: ☐ received: ☐ not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:
4. Date of timely receipt of the required corrections under PCT Article 11(2):
5. International Searching Authority (if two or more are competent): ISA /
6. ☐ Transmittal of search copy delayed until search fee is paid

For International Bureau use only

Date of receipt of the record copy by the International Bureau:

POWER OF ATTORNEY

The undersigned Applicant hereby appoints the following as agent:-

WATERMARK PATENT & TRADE MARK ATTORNEYS
4th Floor, "Durack Centre"
263 Adelaide Terrace
PERTH WA 6000 AUSTRALIA

to represent the undersigned before all the competent International authorities in connection with the International Application identified below.

Title of Invention: Exhaust Gas Treatment and Device.

International Patent Application No. PCT/AU00/01064, dated 8th September, 2000, filed with the Australian Receiving Office and to make or receive payments on behalf of the undersigned

ORBITAL ENGINE (AUSTRALIA) PTY LIMITED.....Albert Ferraloro.....
Patents Manager, Albert Ferraloro

HOUSTON, Rodney Alexander .....

YANG, Koon Chung .....

WORTH, David Richard .....

CATHCART, Geoffrey Paul .....

MOORE, Michael .....

Date: 06.11.2000

P130APC
1099

Please reply to Perth office

September 19, 2001

Our Ref: P15667PCAU MCQ:KMN

International Preliminary Examining Authority
Australian Patent Office
PO Box 200
WODEN ACT 2606

Dear Sir,

Re: International Patent Application No. PCTAU0001064 by
Orbital Engine Company (Australia) Pty Limited

We refer to the Written Opinion mailed on May 4, 2001 on this application.

In response to the Examiner's novelty and inventive step objections, amendments have been made to the claims to more clearly distinguish the claimed invention from the prior art.

New claim 1 is based on claim 1 as originally lodged but further includes the features of original claim 18. New claim 1 now recites "controlling operation of the engine during the first mode so as to promote a selective NOx reduction process at the first catalytic converter". The first mode of operation is a lean mode. NOx is typically generated and absorbed during lean operation of an engine and reduced during rich operation of the engine (when there is an excess of CO available to promote the reduction reaction). None of the documents cited by the Examiner either disclose or teach that NOX could be reduced during lean operation of an engine. We therefore consider that new claim 1 is both novel and involves an inventive step over and above the prior art.

New claims 25 and 40 (based on claims 26 and 38 as originally filed) also refer to the abovenoted engine control operation, and similar comments apply to these claims as would apply to new claim 1.

.../2

New claim 41 (based on claim 39 as originally filed) incorporates the feature of claim 46 as originally filed. NOx is typically stored during lean operation and is reduced during rich operation of the engine. Typically the engine is forced to operate in a rich mode so as to prevent the catalyst from being saturated with NOx. The amended claim says that over a Euro III drive cycle the engine does not need to be actively forced to run in a rich or stoichiometric mode of operation so as to prevent the catalyst from saturating with NOx. None of the citations suggest that this is possible as they are directed to preventing the catalysts from saturating. We therefore consider that claim 41 is both novel and involves an inventive step over the cited prior art.

New claim 64 (based on claim 63 as originally filed) now incorporates the feature of claim 64 as originally filed. New claim 64 recites an engine that operates with a range of air fuel ratios up to "substantially stoichiometric" and that purges the catalyst of NOx over a Euro III cycle. DE19807203 appears to be the only citation that uses a stoichiometric air fuel ratio to purge the catalyst of NOx. However DE19807203 can only achieve this by recirculating NOx released from the NOx store catalyst to a three way catalyst that is located upstream of the NOx store catalyst. Claim 64 does not recirculate exhaust gases to an upstream catalyst in order to purge the system of NOx. It is not obvious from DE19807203 that purging of the catalyst could be achieved with a stoichiometric air fuel ratio without recirculation of the exhaust gas. Moreover it is not obvious from the other citations that reliance on substantially stoichiometric air fuel ratios alone could be sufficient to purge a NOx storage catalyst over a Euro III drive cycle. We therefore consider that new claim 64 is both novel and involves an inventive step over the cited prior art.

We enclose herewith new specification pages 1 to 33 to replace the specification pages 1 to 34 as originally filed.

Yours respectfully,
WATERMARK

Michael Chin Quan

Enc

1954

PATENT COOPERATION TREATY

om the:
TERNATIONAL PRELIMINARY EXAMINING AUTHORITY

WATERMARK
PERTH
RECD - 9 MAY 2001

PCT

):
ATERMARK PATENT & TRADEMARK
TTORNEYS
h Floor, Durack Centre
53 Adelaide Terrace
ERTH W.A. 6000

WRITTEN OPINION
(PCT Rule 66)

Date of mailing *(day/month/year)*	04 MAY 2001
REPLY DUE	within **TWO MONTHS** from the above date of mailing

Applicant's or agent's file reference	International filing date *(day/month/year)*	Priority Date *(day/month/year)*
15667PCAU MCQ:KMN	08 September 2000	08 September 1999
International application No. PCT/AU 00/01064		

International Patent Classification (IPC) or both national classification and IPC

Int. Cl.[7] F 02 D 41/34, 43/04 F02 M 69/42 F02 B 75/10 F 01N 3/18, 3/20

Applicant

1. ORBITAL ENGINE COMPANY (AUSTRALIA) PTY LIMITED et al

1. This written opinion is the **FIRST** drawn by this International Preliminary Examining Authority.
2. This opinion contains indications relating to the following items:.

I	[X]	Basis of the opinion
II	[ ]	Priority
III	[ ]	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	[X]	Lack of unity of invention
V	[X]	Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	[X]	Certain documents cited
VII	[ ]	Certain defects in the international application
VIII	[X]	Certain observations on the international application

3. The applicant is hereby **invited to reply** to this opinion.

When? See the time limit indicated above. The applicant may, before the expiration of that time limit, request this Authority to grant an extension, see Rule 66.2(d).

How? By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3.
For the form and the language of the amendments, see Rules 66.8 and 66.9.

Also For an additional opportunity to submit amendments, see Rule 66.4.
For the examiner's obligation to consider amendments and/or arguments, see Rule 66.4*bis*.
For an informal communication with the examiner, see Rule 66.6.

If no reply is filed, the international preliminary examination report will be established on the basis of this opinion.

4. The final date by which the international preliminary examination report must be established according to Rule 69.2 is: **8 January 2002**

Name and mailing address of the IPEA/AU

AUSTRALIAN PATENT OFFICE
PO BOX 200
WODEN ACT 2606 AUSTRALIA
E-mail address: PCT@IPAUSTRALIA.GOV.AU
Facsimile No. (02) 6285 3929

Authorized Officer

PETER WARD
Telephone No. (02) 6283 2129

WRITTEN OPINION

International application No.
PCT/AU 00/01064

Basis of the opinion

With regard to the elements of the international application:*

[X] the international application as originally filed.

[ ] the description, pages , as originally filed,
pages , filed with the demand,
pages , received on with the letter of .

[ ] the claims, pages , as originally filed,
pages , as amended under Article 19,
pages , filed with the demand,
pages , received on with the letter of .

[ ] the drawings, pages , as originally filed,
pages , filed with the demand,
pages , received on with the letter of .

[ ] the sequence listing part of the description:
pages , as originally filed
pages , filed with the demand
pages , received on with the letter of .

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language which is:

[ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

[ ] the language of publication of the international application (under Rule 48.3(b)).

[ ] the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the written opinion was drawn on the basis of the sequence listing:

[ ] contained in the international application in printed form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readable form.

[ ] The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. [ ] The amendments have resulted in the cancellation of:

[ ] the description, pages

[ ] the claims, Nos.

[ ] the drawings, sheets/fig

5. [ ] This opinion has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).

** Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed"*

ITTEN OPINION

International application No.
PCT/AU 00/01064

ck of unity of invention

In response to the invitation (Form PCT/IPEA/405) to restrict or pay additional fees the applicant has:

- ☐ restricted the claims.
- ☐ paid additional fees.
- ☐ paid additional fees under protest.
- ☐ neither restricted nor paid additional fees.

2. This Authority found that the requirement of unity of invention is not complied with for the following reasons and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees:

The international application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept. In coming to this conclusion the International Searching Authority has found that there are different inventions as follows:

1. Claims 1- 84 relate to exhaust gas treatment for an engine operating at various air-fuel ratios. It is considered that a exhaust gas treatment for an engine operating at various ratios comprises a first " special technical feature".

2. Claims 85- 100 are directed to an engine with exhaust gas treatment with NOx storage capacity and catalyst volume less than 150% of the engine swept volume. It is considered that a catalyst volume less than 150% of the engine swept volume comprises a second " special technical feature ".

Since the above mentioned groups of claims do not share any of the technical features identified, a " technical relationship" between the inventions, as defined in PCT rule 13.2 does not exist. Accordingly the international application does not relate to one invention or to a single inventive concept.

3. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

- [X] all parts.
- ☐ the parts relating to claims Nos.

ITTEN OPINION

International application No.
PCT/AU 00/01064

easoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Statement			
Novelty (N)	Claims	15-17, 29-31, 40, 43, 46-51, 54-62, 64-71, 73-78, 85-100	YES
	Claims	1-14, 18-28, 32-39, 41, 42, 44, 45, 52, 53, 63, 72, 79-84	NO
Inventive step (IS)	Claims	15-17, 29-31, 48-51, 54-62, 67-71, 73-78, 85-10	YES
	Claims	1-14, 18-28, 32-47, 52, 53, 63, 64, 65, 66, 72, 79-84	NO
Industrial applicability (IA)	Claims	1-100	YES
	Claims		NO

2. Citations and explanations

NOVELTY (N) claims 1-14, 18-28, 32-39, 41, 42, 44, 45, 52, 53, 63, 72, 79-84

- US 5778666A
This citation explicitly or implicitly discloses all the features of the claims listed above for example see claim 1 of the citation which discloses treating NOx emissions by operating the engine in a first mode with a lean air to fuel ratio and a second mode with a stoichmetric air fuel ratio.

- DE 19807203 A

This citation explicitly or implicitly discloses all the features of claims 1-6, 13, 14, 23, 25, 26, 27, 28, 37, 38, 63, 80-84 for example see abstract which discloses treating NOx emissions using a catalyst and operating the engine in a first mode with a lean air to fuel ratio and then operating in a second mode with a fuel/air ratio of about 1.
See however indications in Box VI

INVENTIVE STEP (IS) claims 1-14, 18-28, 32-47, 52, 53, 63, 64, 65, 66, 72, 79-84

- US 5778666A

Claims 1-14, 18-28, 32-39, 41, 42, 44, 45, 52, 53, 6, 72, 79-84 as above.

The differences between claims 40, 43, 46, 47, 64, 65, 66 and the citation are considered to be workshop variations and lack an inventive step

Continued.

ITTEN OPINION

International application No.
PCT/AU 00/01064

1. Certain documents cited

Certain published documents (Rule 70.10)

Application No. Patent No.	Publication date (day/month/year)	Filing date (day/month/year)	Priority date (valid claim) (day/month/year)
X JP 20000 87788 A	28 March 2000	9 September 1998	

This document implicitly or explicitly discloses the features of claims 1-12, 21, 23-26, 32-45, 52, 53, 63, 66, 80-84

2. Non-written disclosures (Rule 70.9)

Kind of non-written disclosure	Date of non-written disclosure (day/month/year)	Date of written disclosure referring to non-written disclosure (day/month/year)

WRITTEN OPINION

International application No.
PCT/AU 00/01064

II. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

The invention defined by claims 1,26,38,39,54,63 is not clear due to the various permutations/combinations of integers defined.

Supplemental Box

(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of:

V
-DE 19807203A
Claims 1-6, 13, 14, 23, 25, 26, 27, 28, 37, 38, 63, 80-84 as above.

The differences between claims 64,65 and the citation are considered to be workshop variation and lack an inventive step

Please reply to Perth office

October 17, 2001

Our Ref: P15667PCAU MCQ:KMN

International Preliminary Examining Authority
Australian Patent Office
PO Box 200
WODEN ACT 2606

Dear Sir,

Re: International Patent Application No. PCT/AU00/01064 by
Orbital Engine Company (Australia) Pty Limited

We refer to the Written Opinion mailed on October 11, 2001 on this application.

Please replace the specification presently on file with the new specification showing the correct page numbering.

Yours respectfully,
WATERMARK

Michael Chin Quan

Enc

PATENT COOPERATION TREATY

From the:
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

PCT

WRITTEN OPINION

(PCT Rule 66)

To:
WATERMARK PATENT & TRADEMARK ATTORNEYS
4th Floor, Durack Centre
263 Adelaide Terrace
PERTH W.A. 6000

Date of mailing *(day/month/year)*	11 OCT 2001
Applicant's or agent's file reference: P15667PCAU MCQ:KMN	**REPLY DUE** within **ONE MONTH** from the above date of mailing

International application No.	International filing date *(day/month/year)*	Priority Date *(day/month/year)*
PCT/AU 00/01064	08 September 2000	08 September 1999

International Patent Classification (IPC) or both national classification and IPC

Int. Cl.[7] F 02 D 41/34, 43/04,F02 M 69/42,F02,B 75/10,F 01N 3/18, 3/20

Applicant

1. ORBITAL ENGINE COMPANY (AUSTRALIA) PTY LIMITED et al

1. This written opinion is the **SECOND** drawn by this International Preliminary Examining Authority.
2. This opinion contains indications relating to the following items:.

I	[X]	Basis of the opinion
II	[ ]	Priority
III	[ ]	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	[X]	Lack of unity of invention
V	[X]	Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	[X]	Certain documents cited
VII	[X]	Certain defects in the international application
VIII	[X]	Certain observations on the international application

3. The applicant is hereby **invited to reply** to this opinion.

When? See the time limit indicated above. The applicant may, before the expiration of that time limit, request this Authority to grant an extension, see Rule 66.2(d).

How? By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3. For the form and the language of the amendments, see Rules 66.8 and 66.9.

Also For an additional opportunity to submit amendments, see Rule 66.4.
For the examiner's obligation to consider amendments and/or arguments, see Rule 66.4*bis*.
For an informal communication with the examiner, see Rule 66.6.

If no reply is filed, the international preliminary examination report will be established on the basis of this opinion.

4. The final date by which the international preliminary examination report must be established according to Rule 69.2 is:

Name and mailing address of the IPEA/AU	Authorized Officer
AUSTRALIAN PATENT OFFICE PO BOX 200 WODEN ACT 2606 AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	KURT TOBLER Telephone No. (02) 6283 2469

WRITTEN OPINION

International application No.
PCT/AU 00/01064

I. Basis of the opinion

1. With regard to the **elements** of the international application:*

☐ the international application as originally filed.

☒ the description, pages , as originally filed,
pages , filed with the demand,
pages **1-18,** received on **20 SEPTEMBER 2001.**

☒ the claims, pages , as originally filed,
pages , as amended under Article 19,
pages , filed with the demand,
pages **18-32,** received on **20 SEPTEMBER 2001.**

☒ the drawings, pages **1-5,** as originally filed,
pages , filed with the demand,
pages , received on with the letter of .

☐ the sequence listing part of the description:
pages , as originally filed
pages , filed with the demand
pages , received on with the letter of .

2. With regard to the **language,** all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language which is:

☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

☐ the language of publication of the international application (under Rule 48.3(b)).

☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the written opinion was drawn on the basis of the sequence listing:

☐ contained in the international application in printed form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☐ The amendments have resulted in the cancellation of:

☐ the description, pages

☐ the claims, Nos.

☐ the drawings, sheets/fig

5. ☐ This opinion has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).

** Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed"*

IV. Lack of unity of invention

1. In response to the invitation (Form PCT/IPEA/405) to restrict or pay additional fees the applicant has:

- ☐ restricted the claims.
- ☐ paid additional fees.
- ☐ paid additional fees under protest.
- ☐ neither restricted nor paid additional fees.

2. This Authority found that the requirement of unity of invention is not complied with for the following reasons and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees:

The international application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept. In coming to this conclusion the International Searching Authority has found that there are different inventions as follows:

1. Claims 1- 84 relate to exhaust gas treatment for an engine operating at various air-fuel ratios. It is considered that a exhaust gas treatment for an engine operating at various ratios comprises a first " special technical feature".

2. Claims 85- 100 are directed to an engine with exhaust gas treatment with NOx storage capacity and catalyst volume less than 150% of the engine swept volume. It is considered that a catalyst volume less than 150% of the engine swept volume comprises a second " special technical feature ".

Since the above mentioned groups of claims do not share any of the technical features identified, a " technical relationship" between the inventions, as defined in PCT rule 13.2 does not exist. Accordingly the international application does not relate to one invention or to a single inventive concept.

3. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

- ☒ all parts.
- ☐ the parts relating to claims Nos.

V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-100	YES
	Claims		NO
Inventive step (IS)	Claims	1-100	YES
	Claims		NO
Industrial applicability (IA)	Claims	1-100	YES
	Claims		NO

2. Citations and explanations

The claims as proposed to be amended are novel in the light of the art cited in the International Search Report. The claims (1-84) use of controlling the operation of the engine during a lean air-fuel ratio mode so as to promote a selective NOx reduction process at a first catalytic converter is not taught by the cited art and is therefore novel. Claims 85-100 disclose an engine with a catalyst volume less than 150% of the swept volume of the engine, and is also novel in the light of the cited art.

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

Application No. Patent No.	Publication date *(day/month/year)*	Filing date *(day/month/year)*	Priority date (valid claim) *(day/month/year)*
PX JP 20000 87788 A	28 March 2000	9 September 1998	

2. Non-written disclosures (Rule 70.9)

Kind of non-written disclosure	Date of non-written disclosure *(day/month/year)*	Date of written disclosure referring to non-written disclosure *(day/month/year)*

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

The application as proposed to be amended has two pages numbered 18.

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

The invention defined by claims 1,25,40,41,55 and 64 is not clear due to the various permutations/combinations of integers defined.

14

REC'D 19 NOV 2001
PCT

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P15667PCAU	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).
International Application No. **PCT/AU00/01064**	International Filing Date *(day/month/year)* 8 September 2000	Priority Date *(day/month/year)* 8 September 1999

International Patent Classification (IPC) or national classification and IPC

Int. Cl. [7] F02D 41/34, 43/04, F02M 69/42, F02B 75/10, F01N 3/18, 3/20

Applicant

ORBITAL ENGINE COMPANY (AUSTRALIA) PTY LIMITED et al

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   [X] This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of **34** sheet(s).

3. This report contains indications relating to the following items:

I	[X]	Basis of the report
II	[ ]	Priority
III	[ ]	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	[X]	Lack of unity of invention
V	[X]	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	[X]	Certain documents cited
VII	[ ]	Certain defects in the international application
VIII	[X]	Certain observations on the international application

Date of submission of the demand	Date of completion of the report
13 March 2001	29 October 2001 13 NOV 2001
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer **KURT TOBLER** Telephone No. (02) 6283 2469

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/AU00/01064

I. Basis of the report

1. With regard to the **elements** of the international application:*

☐ the international application as originally filed.

☒ the description, pages , as originally filed,
pages , filed with the demand,
pages **1-19,** received on **17 October 2001.**

☒ the claims, pages , as originally filed,
pages , as amended (together with any statement) under Article 19,
pages , filed with the demand,
pages **20-34,** received on **17 October 2001.**

☒ the drawings, pages **1-5,** as originally filed,
pages , filed with the demand,
pages , received on with the letter of

☐ the sequence listing part of the description:
pages , as originally filed
pages , filed with the demand
pages , received on with the letter of

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language which is:

☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

☐ the language of publication of the international application (under Rule 48.3(b)).

☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

4. ☐ The amendments have resulted in the cancellation of:

☐ the description, pages

☐ the claims, Nos.

☐ the drawings, sheets/fig.

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report*

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

☐ restricted the claims.

☐ paid additional fees.

☐ paid additional fees under protest.

☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied with and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

☐ complied with.

☒ not complied with for the following reasons:

The international application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept. In coming to this conclusion the International Searching Authority has found that there are different inventions as follows:

1. Claims 1- 84 relate to exhaust gas treatment for an engine operating at various air-fuel ratios. It is considered that a exhaust gas treatment for an engine operating at various ratios comprises a first " special technical feature".

2. Claims 85- 100 are directed to an engine with exhaust gas treatment with NOx storage capacity and catalyst volume less than 150% of the engine swept volume. It is considered that a catalyst volume less than 150% of the engine swept volume comprises a second " special technical feature ".

Since the above mentioned groups of claims do not share any of the technical features identified, a " technical relationship" between the inventions, as defined in PCT rule 13.2 does not exist. Accordingly the international application does not relate to one invention or to a single inventive concept.

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

☒ all parts.

☐ the parts relating to claims Nos.

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	**1-100**	**YES**
	Claims		**NO**
Inventive step (IS)	Claims	**1-100**	**YES**
	Claims		**NO**
Industrial applicability (IA)	Claims	**1-100**	**YES**
	Claims		**NO**

2. Citations and explanations (Rule 70.7)

The claims as proposed to be amended are novel in the light of the art cited in the International Search Report. The claims (1-84) use of controlling the operation of the engine during a lean air-fuel ratio mode so as to promote a selective NOx reduction process at a first catalytic converter is not taught by the cited art and is therefore novel. Claims 85-100 disclose an engine with a catalyst volume less than 150% of the swept volume of the engine, and is also novel in the light of the cited art.

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

Application No. Patent No.	Publication date *(day/month/year)*	Filing date *(day/month/year)*	Priority date (valid claim) *(day/month/year)*
P,X JP 20000 87788 A	28 March 2000	9 September 1998	

This document implicitly or explicitly discloses the features of claims 1-12, 21, 23-26, 32-45, 52, 53, 63, 66, 80-84.

2. Non-written disclosures (Rule 70.9)

Kind of non-written disclosure	Date of non-written disclosure *(day/month/year)*	Date of written disclosure referring to non-written disclosure *(day/month/year)*

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

The invention defined by claims 1, 26, 38, 39, 54 and 63 is not clear due to the various permutations/combinations of integers defined.

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Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: EXHAUST GAS TREATMENT METHOD AND DEVICE

(57) Abstract: A method of treating NOx emissions in the exhaust gas of an internal combustion engine having catalyst means including at least a first catalyst converter capable of treating NOx, the method including operating the engine in a first mode to promote a first set of conditions and in a second mode to promote a second set of conditions, wherein the first mode of operation includes operating the engine with a lean air-fuel ratio, and the second mode of operation includes operating the engine with a stoichiometric air-fuel ratio.

WO 01/18374 A1

EXHAUST GAS TREATMENT METHOD AND DEVICE

Introduction

This invention relates to the treatment of oxides of nitrogen within the exhaust gas emissions of internal combustion engines, and in particular to a method of operating an internal combustion engine to allow such treatment.

The recent and future introduction of increasingly strict internal combustion engine emissions legislation around the world, particularly as this relates to automotive vehicles, has resulted in increasing pressure on engine and vehicle manufacturers to reduce engine emissions, particularly hydrocarbon (HC), carbon monoxide (CO), and oxides of nitrogen (NOx) emissions. These emissions are generally treated by a catalytic converter in the exhaust system of the engine, which is intended to convert these potentially harmful gases into preferred substances such as carbon dioxide, nitrogen, oxygen, and water.

NOx emissions present particular challenges for engine and vehicle manufacturers in that typical catalytic converters have been found to be less effective when the engine is operating under lean burn conditions. This is particularly a problem in engines which derive efficiency advantages from lean burn operation, and in particular, stratified charge engines, such as some of those incorporating the Applicant's dual fluid fuel injection system.

Dual fluid fuel injection systems typically utilise compressed gas during each injection event to entrain and atomise a metered quantity of fuel for delivery into the combustion chambers of an internal combustion engine. The Applicant has developed such fuel injection systems and one version thereof is described in the Applicant's U.S. Patent No. 4934329, the details of which are incorporated herein by reference. Generally, a source of compressed gas, for example an air compressor, is required for these fuel injection systems to operate satisfactorily. The term "air" is used herein to refer not only to atmospheric air, but also to other gases including air and exhaust gas or fuel vapour mixtures. In operation, such dual fluid fuel injection systems typically rely on the existence of a differential pressure between the fuel which is metered for subsequent delivery and the compressed gas, typically air, which is used to deliver the fuel to the engine. In this regard, it is normal that the fuel pressure is slightly higher than the air

pressure such that the fuel may be metered into a volume of compressed gas in a manner akin to that described in U.S. Patent No. 4934329.

Prior Art

Various methods of engine operation and engine exhaust systems have been proposed to overcome the problem of NOx emissions. One known example, set out in US patent no 5433074, proposes the use of a specific NOx adsorbent layer in the catalyst. This layer or coating is intended to absorb NOx emissions under typical low NOx conversion conditions (that is, during lean burn operation of the engine) and release the absorbed NOx under typical high NOx conversion conditions (that is, during richer than stoichiometric operation of the engine). The adsorbent layer is a NOx adsorbent material including Barium (Ba).

However fuel economy in a system utilising such catalysts can be compromised by the requirement of periodic "flushing" of the system with a rich air-fuel mixture. Further, in order to ensure effective operation of the system, additional sensors may be required to provide feedback to the engine controller for the purpose of determining whether "flushing" is required. The system may also be temperature sensitive, and damage to the adsorbent layer may occur at temperatures above 750 degrees Celsius, whilst effective operation of the storage capacity may be limited to a window of around 300 to 550 degrees Celsius.

Summary of the Invention

It is the aim of this invention to provide an alternative NOx treatment method and device, which overcomes at least some of the disadvantages of the prior art systems.

In accordance with a first aspect of the present invention, there is provided a method of treating NOx emissions in the exhaust gas of an internal combustion engine having catalyst means including at least a first catalyst converter capable of treating NOx the method including operating the engine in a first mode to promote a first set of conditions and in a second mode to promote a second set of conditions, wherein the first mode of operation includes operating the engine with a lean air-fuel ratio, and the second mode of operation includes operating the engine with a stoichiometric air-fuel ratio.

Conveniently, the catalyst means includes a first catalyst converter arranged in an exhaust system of the engine. Preferably, the first set of

conditions include exhaust gases with a lean air-fuel ratio and lower relative temperatures. Conveniently, the second set of conditions include exhaust gases with a stoichiometric air fuel ratio. In many cases, the second.set of conditions will include higher relative exhaust gas temperatures. Preferably, the exhaust gas temperatures produced by the engine whilst it operates under the first mode of operation are in the range 200 to 400 degrees Celsius. Preferably, the exhaust gas temperatures produced by the engine whilst it operates under the second mode of operation are greater than 200 degrees Celsius, and typically the exhaust gas temperatures are greater than 400 degrees Celsius. Preferably the relevant exhaust temperature is that of the exhaust gas at the first catalytic converter. Preferably the temperature of the exhaust gas is controlled by way of appropriate operation of the engine to ensure effective operation of the first catalytic converter under the first mode of operation. Preferably the temperature of the exhaust gas in this case is controlled to be within the range 200 to 400 degrees Celsius. Preferably the temperature of the exhaust gas is controlled controlled by way of appropriate operation of the engine to ensure effective operation of the first catalytic converter under the second mode of operation. Preferably the temperature of the exhaust gas in this case is to be greater than approximately 400 degrees Celsius. Conveniently, the operation of the engine is controlled during the first mode so as to generate the exhaust gas emissions having characteristics that can support acceptable levels of NO_x conversion within the first catalytic converter.

Preferably the first catalytic converter includes a combination of Pt (or Pd), Rh and Ba elements. Preferably, the first catalytic converter comprises a greater proportion of Pt (ie: it is "Pt rich") than would be expected in a typical three way catalyst. Preferably the ratio of Pt to Rh in the first catalytic converter is 10:1. Preferably, the proportion of Ba in the first catalyst converter is relatively low as compared to the proportions of Pt and Rh. Preferably, the operation of the engine during the first mode is controlled so as to promote a selective catalyst reduction process at the first catalytic converter which is normally not supported during lean burn operation. The composition of the first catalytic converter is preferably slightly different to that expected in a typical three way catalyst comprising pt (or Pd) and Rh. Conveniently, the subtle difference in the composition of the first

catalyst converter together with the promotion of the first set of conditions during the first mode enable the achievement of higher NO_x emission efficiencies than would otherwise be expected form a typical three way catalyst during the said first mode of operation.

Conveniently, the operation of the engine is controlled during the second mode so as to promote high NO_x conversion efficiency levels within the first catalytic converter.

Preferably a temperature sensing device is provided in the exhaust system of the internal combustion engine, and the output from the temperature sensing device is used to determine the mode of operation of the internal combustion engine. Preferably a sensed temperature of between 200 and 400 degrees Celsius will result in operation of the engine under the first mode of operation. Preferably a sensed temperature of greater than 400 degrees Celsius will result in operation of the engine under the second mode of operation. This latter mode of operation will typically equate to high engine load operating conditions wherein the temperatures of the exhaust gas are usually higher than during lean burn operation.

Preferably the first catalytic converter is provided in the exhaust system at a position sufficiently downstream of the internal combustion engine that the exhaust gas is allowed to cool somewhat before entering the first catalytic converter.

Preferably a second catalytic converter is provided in a close coupled configuration with the internal combustion engine for the purpose of oxidising hydrocarbon and carbon monoxide emissions in the engine exhaust gases. Preferably the first catalytic converter is a three way catalyst. Conveniently, the engine is direct injected. Preferably, fuel injection to the engine is effected by way of a two fluid fuel injection system.

According to another aspect of the present invention, there is provided an engine exhaust system for treating NOx emissions in the exhaust gas of an internal combustion engine, including catalyst means having at least a first catalyst converter capable of treating NOx, wherein the engine exhaust system is adapted to treat the NOx emissions when the engine is operated in a first mode to promote a first set of conditions and in a second mode to promote a second set of

conditions, the first mode of operation including operating the engine with a lean air-fuel ratio, and the second mode of operation including operating the engine with a stoichiometric air-fuel ratio.

According to a further aspect of the present invention, there is provided an electronic control unit for controlling an internal combustion engine having catalyst means including at least a first catalyst converter capable of treating NOx, the electronic control unit operating the engine in a first mode to promote a first set of conditions and in a second mode to promote a second set of conditions, wherein the first mode of operation includes operating the engine with a lean air-fuel ratio, and the second mode of operation includes operating the engine with a stoichiometric air-fuel ratio to thereby treat NOx emissions in the exhaust gas of the engine.

Preferred Embodiment of the Invention

It will be convenient to further describe the invention with respect to the accompanying drawings that assist in describing various possible arrangements of the present invention. Other arrangements of the invention are however possible, and consequently, the particularity of the accompanying drawings is not to be understood as superseding the generality of the preceding description of the invention.

In the drawings:

Figure 1 is a schematic partial cross-sectional view of an internal combustion engine having a dual fluid fuel injection system operatively arranged with respect thereto;

Figure 2 is a partial cross-sectional view of one form of a fuel metering and injector rail unit;

Figure 3 is a schematic layout of an internal combustion engine and exhaust system according to an embodiment of the present invention; and

Figure 4 is a graph showing engine load against engine speed for an engine operating in accordance with an embodiment of the present invention.

Figure 5 is a flow chart describing how selection between the various modes of operation detailed in Figure 4 may be effected.

As referred to above, emissions legislation is being introduced around the world that requires engine and vehicle manufactures to reduce the emissions

produced by various types of vehicles. An example of such legislation that is applicable to Europe is commonly referred to as the Euro III and Euro IV emissions targets and should be well known to those skilled in the relevant art.

The Euro III and Euro IV emissions targets for passenger vehicles powered only by gasoline in respect of HC, CO and NOx emissions are:

TEST	EMISSIONS	UNIT	EC 2000 (EURO III)	EC 2005 (EURO IV)
Rev. ECE + EUDC	HC	g/km	0.2	0.1
	NOx		0.15	0.08
	CO		2.3	1.0

Passenger Vehicles (≤ 2.5t gross vehicle weight)

To make these measurements of vehicle emissions, a vehicle is typically operated on a dynamometer. The dynamometer is caused to operate with a specific drive cycle that simulates certain real world driving conditions. Euro III and Euro IV have specific drive cycles over which the emissions referred to above are measured, these drive cycles are referred to as the ECE and the EUDC drive cycles.

The emissions that are measured are referred to as tail pipe emissions as they are emitted from the exhaust pipe (often referred to as the "tail pipe") of the vehicle. In a typical vehicle, emissions from the engine (often referred to as "engine out" emissions) are treated by an exhaust treatment system that typically utilises a catalytic converter which promotes further reduction and oxidation of engine out emissions so that the tail pipe emissions contain a greater proportion of N_2, O_2, CO_2, and H_2O than the engine out emissions. Hence the Euro III and Euro IV emissions specify maximum levels of tail out emissions of hydrocarbons, carbon-monoxide and oxides of Nitrogen for various classes of vehicles.

It is preferable that in meeting these emissions targets that the vehicle also have a fuel economy benefit over currently available MPI (Manifold Port Injected) engines and DI (Direct Injection) engines.

The Applicant has developed certain engines which utilise a two fluid direct fuel injection system. Simple application of such fuel injection systems to four stroke engines is not, in itself, sufficient to meet these emissions targets and further refinement is required before the above emissions targets can be met. In particular it is necessary to calibrate an engine at various points on the speed load curve (for example the speed load curve detailed in Figure 4) in order for it to meet these emissions targets. Calibration however is a multi-variable, typically non-linear problem. In a direct injection engine particularly, it involves consideration of variables such as ignition timing, fuel per cycle, air fuel ratio, exhaust gas re-circulation levels, injection timings etc.

To fully understand how these emissions targets may be met by use of such a fuel system, the Applicant's two fluid fuel injection system will first be described in some detail with reference to Figures 1 and 2, and then a description of the application of the present invention to an engine with that fuel injection system will follow with particular reference to Figures 3 and 4. However, it is believed that application of the present invention need not be limited to engines with the described fuel supply system, which it will be understood is set out for the purposes of exemplification only. It may also be applicable to other engines with similar emissions capabilities as the applicants engines.

Figure 1 shows a direct injected four stroke internal combustion engine 20 comprising a fuel injection system, the engine 20 having an air intake system 22, an ignition means 24, a fuel pump 23, and fuel reservoir 28. An air compressor 29 is operatively arranged with respect to the engine 20 and typically driven off the engine crankshaft 33 or other drive-train by way of a suitable belt (not shown). Mounted in the cylinder head 40 of the engine 20 is a fuel and air rail unit 11. The fuel pump 23 draws fuel from the fuel reservoir 28 which is then supplied to the fuel and air rail unit 11 though a fuel supply line 55. Conventional inlet and exhaust valves 15 and 16 are also mounted in the cylinder head 40 in the known manner together with conventional cam means 17 for actuating the valves 15, 16. The valves 15, 16 are arranged to open and close corresponding inlet and exhaust ports 18 and 19 for admission of fresh air and the removal of exhaust gases from the engine cylinder in the known manner.

Referring now to Figure 2, there is shown in detail a fuel and air rail unit 11

which, whilst being different in design from that shown in Figure 1, shares all the same components thereof. The fuel and air rail unit 11 comprises a fuel metering unit 10 and an air or delivery injector 12 for the or each cylinder of the engine 20. The fuel metering unit 10 is commercially available and requires no detailed description herein. Suitable ports are provided to allow fuel to flow through the fuel metering unit 10 and a metering nozzle 21 is provided to deliver fuel to a passage 90 and thence to the air injector 12. The body 8 of the fuel and air rail unit 11 may be an extruded component with a longitudinally extending air duct 13 and a fuel supply duct 14.

As best seen in Figure 1, at appropriate locations, there are provided connectors and suitable ducts communicating the rail unit 11 with air and fuel supplies: air line 49 communicating air duct 13 with the air compressor 29; air line 53 providing an air outlet which returns air to the air intake system 22; and fuel line 52 communicating the fuel supply duct 14 the fuel reservoir 28 providing a fuel return passage. The air duct 13 communicates with a suitable air regulator 27 which regulates the air pressure of the compressed air provided by the air compressor 29 to the air duct 13.

Referring again to Figure 2, the air injector 12 has a housing 30 with a cylindrical spigot 31 projecting from a lower end thereof, the spigot 31 defining an injection port 32 communicating with passage 90. The injection port 32 includes a solenoid operated selectively openable poppet valve 34 operating in a manner similar to that as described in the Applicant's U.S. Patent No. 4934329, the contents of which are hereby incorporated by reference. As best seen in Figure 1, energisation of the solenoid in accordance with commands from an electronic control unit (ECU) 100 causes the valve 34 to open to deliver a fuel-gas mixture to a combustion chamber 60 of the engine 20. However, it is not intended to limit the valve construction to that as described above and other valves, for example, pintle valve constructions, could be employed. The electronic control unit (ECU) 100 typically receives signals indicative of crankshaft speed and airflow from suitably located sensors within the engine (not shown). The ECU 100, which may also receive signals indicative of other engine operating conditions such as the engine temperature, ambient temperature and battery voltage (not shown), determines from all input signals received the quantity of fuel required to be

delivered to each of the cylinders of the engine 20. As alluded to hereinbefore, this general type of ECU is well known in the art electronically controlled fuel injection systems and will not be described herein further detail.

The opening of each injector valve 34 is controlled by the ECU 100 via a respective communicating means 101 in timed relation to the engine cycle to effect delivery of fuel from the injection port 32 to a combustion chamber 60 of the engine 20. By virtue of the two fluid nature of the system, fuel is delivered to the cylinder entrained in a gas. The passage 90 is in constant communication with the air duct 13 via the conduit 80 as shown in Figure 2 and thus, under normal operation, is maintained at a substantially steady air pressure. Upon energisation of the solenoid of the air injector 12, the valve 34 is displaced downwardly to open the injection port 32 so that a metered quantity of fuel delivered into the air injector 12 by the fuel metering unit 10 is carried by air through the injection port 32 into the combustion chamber 60 of a cylinder of the engine 20.

Typically, the air injector 12 is located within the cylinder head 40 of the engine 20, and is directly in communication with the combustion chamber 60 defined by the reciprocation of a piston 61 within the engine cylinder. As above described, when the injection port 32 is opened and the air supply available via the conduit 80 is above the pressure in the engine cylinder, air will flow from the air duct 13 through the passage 80, passage 90 and, entrained with fuel, injection port 32, into the engine combustion chamber 60.

Turning now to Figure 3, a new set of reference numerals have been adopted due to the schematic nature of this illustration. The features illustrated include engine 200, fuel intake 202, air intake 204, close coupled catalytic converter 206, main catalytic converter 208 and external exhaust outlet 210. A temperature sensor 214 is located adjacent the entry to the main catalytic converter 208.

As is usual in the operation of engine systems of this type, fuel and air are taken in through their respective intakes 202, 204. Combustion then takes place in the engine 200, and exhaust gases pass out of the engine 200. In this Figure, there is illustrated an optimal coupled catalytic converter 206 through which the exhaust gases may pass immediately as they leave the combustion chamber of the engine 200. Exhaust gases then travel along exhaust pipe 212 to the main

catalytic converter 208, and subsequently out the external exhaust outlet 210. The catalytic converter 208 may for example be an underbody catalyst arranged to be a specified distance downstream of an exhaust port (not shown) of the engine.

The engine operation includes two major modes, and two transitional modes (although the engine need not necessarily operate under these modes at all times and other modes of operation are possible). Preferred modal operation of the engine is best shown in Figure 4, which shows a load speed curve for engine operation. Engine load is represented as Break Mean Effective Pressure (BMEP).

In lean operation mode (indicated by reference numeral A), the engine is calibrated to operate in lean burn mode, with a stoichiometric coefficient of preferably greater than 1.3. (ie: The stoichiometric coefficient is 1 for a stoichiometric air-fuel ratio, greater than 1 for a lean air-fuel ratio, and less than 1 for a rich air-fuel ratio.) In the stoichiometric ratio mode (indicated by reference numeral C), the air-fuel ratio is maintained at a substantially stoichiometric level with a stoichiometric coefficient of substantially 1.0. Preferably exhaust gas is re-circulated to the combustion chambers to comprise greater than 25% by mass of the gas in the chamber under lean modes of operation and preferably no greater than 40%. The amount of exhaust gas increasing as the air fuel ratio gets leaner. Exhaust gas may also be re-circulated to the combustion chambers in stoichiometirc modes of operation, however dual injection of fuel, as detailed further herein, is preferably employ

Engine operation is preferred in either one of these major modes of operation, however, a first transition mode (indicated by reference numeral B) may be required when transferring between stoichiometric mode C and lean mode A. A transitional peak mode (indicated by reference numeral D) may also be provided, and is used for specific high load operation for generally temporary operation using a fuel rich air-fuel ratio (stoichiometric coefficient less than 1).

During the lean mode operation A, the temperature of the exhaust gas at the entry to the main catalyst 208 is preferably in the range of 200 to 400 degrees Celsius. In stoichiometric operation C, the temperature of the exhaust gas at the entry to the main catalyst 208 is typically above 400 degrees Celsius.

Conveniently, in this latter mode of operation, the engine can be controlled by way of a dual injection strategy such as that disclosed in the Applicants' International Patent Application No. PCT/AU98/01004, the contents of which are included herein by reference.

Control of the system can be performed in two different ways. Firstly, the mode of the engine can be controlled on the basis of the known or estimated temperature of the exhaust gas. In this case, a sensor 214 can provide information to the engine management system for the purposes of controlling the engine operation appropriately. Secondly, the temperature of the exhaust gas can be controlled to fit the mode of operation under which the engine is currently operating or is desired to operate. Exhaust gas temperature may be controlled, for example, by varying ignition timings from cycle to cycle (corresponding variations of fuelling level may also be required). Of course, a combination of these two methods of control can also be used.

The main catalytic converter 208 is a three way converter which catalytically treats hydrocarbons, carbon monoxide gases and nitrous oxides. The Applicant has found that a Pt-Rh-Ba catalytic converter is particularly useful, and specifically has found that the characteristics of a Johnson-Matthey development version D268/JM370 provides especially good results. This catalytic converter has a ratio of Pt:Rh of 10:1 in the catalytically active part of the converter. The catalytic converter also has a small proportion of Ba therein.

It is believed that the operation of the engine 200 in mode A so as to promote exhaust gases with a lean air fuel ratio and relatively lower gas temperatures supports a selective NO_x reduction process that is not typically supported by a normal 3 way catalyst. It is further believed that this selective NO_x reduction process is further supported by the presence of a Pt rich catalytic converter, and perhaps still further by the presence of some Ba on the converter. This selective NO_x reduction process promotes the reduction of NO_x emissions down to the less harmful components such as N_2O, N_2 and O_2. Alternate theory suggests that the Ba may, at least in part, provide NOx adsorbtion capabilities, and may even act as a catalyst commonly referred to as a Lean NOx Trap (LNT) or Lean NOx Catalyst (LNC). This allows some of the NOx to be stored for conversion into less

harmful emissions when the engine operates in mode C as described in greater detail herein.

In mode C, the engine 200 is controlled in such a way to take advantage of the high conversion efficiencies that the catalyst converter 208 can provide under stoichiometric operating conditions, these conditions being synonymous with higher exhaust gas temperatures and higher load operating points.

The use of the close coupled catalytic converter 206 as illustrated in Figure 3 can increase the effectiveness of the overall emission reduction process by oxidising hydrocarbon and carbon monoxide emissions under conditions which produce lower temperature exhaust gases (for example, the lean mode operation) as the temperature of the exhaust gases immediately adjacent the engine are significantly greater than downstream at the main catalytic converter 208. The reason this is beneficial is that these emissions (hydrocarbons and carbon monoxide) are more efficiently catalysed at higher temperatures. The combined lean stratified and stoichiometric NO_x treatment according to the present embodiment enables some of the potential problems of prior art systems and in particular NO_x storage type methods to be avoided as the catalyst may be purged of NOx by operating the engine under stoichiometric conditions.

In an alternate embodiment, a three way catalyst may be re-located from a close coupled position to an underbody position. An underbody position is a position remote from the engine bay and associated fire wall, and is typically between the ground and the underside of the floor of the vehicle. In this instance the three way catalyst is preferable located in a position adjacent a catalyst having NOx adsorbent properties, such as a catalyst having Ba as a constituent. Preferably, the catalyst having NOx adsorbent properties operates additionally as a three way catalyst. The three way catalyst that has been re-located to an underbody position is preferably located in a single canister together with the catalyst having NOx adsorbent properties. Preferably the three way catalyst is located at the inlet of the canister and the catalyst with NOx adsorbent properties is located at the outlet of the canister. Locating the three way catalyst adjacent the inlet of the canister allows the three way catalyst to be heated by the exhaust gasses emitted from the engine. This transfer of heat to the three way catalyst also serves to cool the exhaust before it flows through the catalyst with NOx adsorbent

properties. In this way both the three way catalyst and the catalyst with NOx adsorbent properties are generally maintained within their respective windows of operational temperatures. Some control of the engine may be required to achieve this. Specifically control of variables such as fuel per cycle and ignition timing may also be implemented to maintain exhaust gas temperatures in a range sufficient to keep the catalysts in their operational temperature windows. As the three way catalyst is now located in an underbody position it is preferable that it is rapidly heated at starting of the engine. Such heating being commonly referred to as a light off strategy and may be achieved through use of a heating element such as a resistive heating element or by use of exhaust gases as detailed in the Applicants US patent 5,655,365 or any other suitable means. It has been found that optimum results may be achieved by location of the underbody catalyst a distance of between 1.0m and 1.5m along the exhaust system from the engine.

In a further embodiment, the three way catalyst and catalyst with NOx adsorbent properties form separate parts of the same three way catalyst brick. The catalyst with NOx adsorbent properties forming that part of the brick to which Ba is added.

With these arrangements, the catalyst with the NOx adsorbent properties may be regenerated by operating the engine with a stoichiometric air fuel ratio (note: regeneration of a NOx adsorbent catalyst is often referred to as "purging" the catalyst).

It is preferable that when operating the engine in mode A, ie lean mode, that the combustion chamber gas comprise 25% or more EGR by mass. EGR being an acronym for Exhaust Gas Re-circulation. EGR means re-circulation of some of the exhaust gasses into the inlet manifold of the engine and hence into the combustion chambers of the engine.

Preferably the combustion chamber gases comprise between 25% and 40% EGR by mass with the percentage of EGR increasing as the air fuel ratio increases (ie as the air fuel ratio gets more lean).

By maintaining the engine out NOx to a level of approximately twice the Euro III tail pipe emissions, the applicant has found the above referenced three way catalyst with NOx adsorbent properties to be particularly effective. It is believed that with PGM (precious group metals – ie Pt, Pd, Rh etc) loadings that are relatively standard for manifold port injected vehicles, engine out NOx emissions

of between three and four times Euro III may be emitted whilst the catalyst will still be effective for meeting Euro III requirements. Such a catalyst having an engine swept volume (ESV) of less than 150% and preferably less than 110%. It is believed that engine out CO emissions should at the same time be in the order of three times or less Euro III emissions in order to meet Euro III emissions requirements. Further it is believed that the engine out HC emissions should be in the order of ten times or less Euro III emissions in order to meet Euro III emissions. Preferably the engine is calibrated across its speed load range so that its emissions do not to exceed these limits over a particular drive cycle. This may require that when the engine is operated in a lean mode that the air fuel ratio correspond with a lambda value no less than 1.3. More over as the lambda value increases, the EGR percentage should also generally increase to a limit of approximately 40%. In some circumstances, an air fuel ratio corresponding to a lambda of between 1.0 and 1.3 may be selected when transitioning between a lean air fuel ratio operating point and a stoichiometric air fuel ratio operating point. Selection of whether a load point should be lean or stoichiometric, and if lean, the limit to which it can be lean is generally determined for an engine during calibration. A trade off between lean operation, power requirements, NOx levels and levels of other emissions will be required. However, to meet Euro III and Euro IV requirements at least, it is believed that lean operating points should be calibrated to have ISNOx (Indicated Specific NOx) emissions levels in the range between 0.7 and 2.0 grams per kilowatt hour in order for a three way catalyst with some NOx adsorbent properties to be utilised. It is believed that by calibrating the engine so that the emissions are maintained in the above bounds that PGM loadings similar to current MPI vehicles may be utilised. Optimally, the catalyst may have a size of less than 150% ESV (engine swept volume) and preferably less than 110% ESV. This range of calibration points is believed to provide optimum operation of an engine capable of generating engine out NOx of approximately one and one half times Euro III levels, three times Euro III CO levels and ten times Euro III HC levels. Calibration with lower NOx levels may be possible, however a larger three way catalyst may be required and fuel consumption may also deteriorate. Hence it is believed that the above range of ISNOx in combination with an exhasut treatment system having a three way

catalyst and a catalyst having some NOx adsorbent properties provides an optimum configuration for meeting Euro III and / or Euro IV emissions targets.

Selection between air fuel ratio and modes A, B, C and D is demonstrated with reference to the dual mode strategy detailed in Figure 5 which may be executed by an electronic control unit (ECU) of the engine. The dual mode strategy commences at step 500 whereupon it proceeds to step 505 where the current gear of the vehicle is identified, typically, first second, third, fourth or fifth for a manual passenger vehicle. Having determined the current gear, the process proceeds to step 510 which decides to branch to step 515 if the gear identified is a low gear, typically first and second, and to branch to step 535 if the gear is a high gear, typically third gear or higher. At step 515 a variable E1, which is an engine load threshold value is set to a predetermined level corresponding to F_Low. This value indicates the boundary between modes B and C in Figure 4. The process then proceeds to step 520 where it determines whether or not the engine is currently operating in an air led mode (typically stoichiometric or rich air fuel ratio and corresponding to high load demand) or a fuel led mode (typically lean air fuel ratio corresponding to low load demand). If the engine is operating in an air led mode then the process moves to step 530, otherwise it moves to step 525 and the value of E1 is reduced by an amount L1, which is a low gear hysteresis number which defines a hysteresis band for transitioning from an air led mode to a fuel led mode (ie, a hysteresis for engine loads when moving from Mode C to Mode A) under low gear operating conditions, after which the process moves to step 530.

Returning to step 510, if the vehicle is in a high gear then the process moves to step 535 and the engine load threshold variable "E1" is set to F_High, being a high load value. The process then moves to step 540 where it is determined whether or not the engine is currently operating with an air led mode or a fuel led mode. If it is operating with an air led mode then the process moves to step 530, otherwise the process moves to step 550 where the engine load threshold value is reduced by the high gear hysteresis number which defines a hysteresis band for transitioning from an air led mode to a fuel led mode (ie, a hysteresis for engine loads when moving from Mode C to Mode A) under high gear operating conditions, after which the process moves to step 530.

At step 530 the process determines whether or not the current engine load is greater than the current engine load threshold E1. If it is not, then the process moves to step 555 and a fuel led (or lean air fuel ratio) is identified and the engine operates in mode A.

If at step 530 the current engine load is greater than the current engine threshold value E1 then the process moves to step 565 and operation in Mode A is identified. Mode A is typically an air led mode. The process then moves to step 570 where if the engine load is greater than engine threshold value E2 then the engine operates in Mode D, which is a mode with rich air fuel ratios. If however at step 570 the current engine load is identified as being less than E2 then the process moves to step 580 which corresponds with Mode C, ie a stoichiometric air fuel ratio.

In preferred embodiments, an additional step 585 may be introduced intermediate step 570 and step 580. This step may determine whether or not the exhaust gas is within a predetermined range, such as range suitable for efficient operation of a catalyst with NOx adsorbent characteristics. If it is within this range, then the process may then operate at additional step 590 in Mode B.

In a further embodiment, the catalyst with NOx adsorbent properties may be regenerated at a sufficient rate when operating the engine with a stoichiometric air fuel ratio (ie lambda = 1.0) that saturation of the catalyst can be avoided. This allows the engine to operate under typical driving conditions such that a NOx sensor may not be required. As such the air fuel ratio for engine load conditions may be selected independently of NOx stored on the catalyst or calculated as stored on the catalyst. This is because the engine load will typically dictate stoichimetic or rich operating conditions from time to time. As such, this intermittent operation at these lower air fuel ratios, as occurs under typical vehicle operating conditions, will often be sufficient to maintain the catalyst in a non-saturated state.

Alternately, the catalyst may be monitored, either directly by a NOx sensor or indirectly by some other means, such as an exhaust gas temperature sensor. Where it is monitored directly, the engine can be operated by selecting a stoiciometric air fuel ratio from time to time so as to ensure that the catalyst does not saturate. Such an arrangement having an advantage that the fuel economy is

not greatly penalised as may be the case where the engine is operate with a rich air fuel ratio.

Indirect monitoring of the NOx stored on the catalyst may be achieved by a cumulative measure of NOx emitted from the engine. This may be achieved by monitoring the engine operating conditions over a period of time. For example the period of time that the engine has spent at various operating points. If it is known the amount of NOx that is likely to be emitted at these operating points then the amount of NOx can be estimated. These operating points may be identified as either one of engine speed or engine load or both. In these circumstances, the engine may be deliberately operated with a stoichiometric air fuel ratio, even though a lean air fuel ratio may be sufficient for current engine operating conditions, so as to regenerate the NOx adsorbent catalyst.

Alternate methods of estimating when to have stoichiometic excursion from a lean mode of operation so as to regenerate the catalyst may be employed. For example, the amount of time since a stoichiometric excusion last occurred or the amount of time since the engine last operated with a stoiciometric operating condition for a period of time to purge the catalyst of a significant proportion of the NOx adsorbed thereto.

The method according to the present invention is applicable to both two stroke and four stroke engines incorporating direct injection systems and particularly those operation with a dual fluid fuel injection system. Modifications and variations as would be deemed obvious to the person skilled in the art are included within the ambit of the present invention.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of treating NOx emissions in the exhaust gas of an internal combustion engine having catalyst means including at least a first catalyst converter capable of treating NOx, the method including operating the engine in a first mode to promote a first set of conditions and in a second mode to promote a second set of conditions, wherein the first mode of operation includes operating the engine with a lean air-fuel ratio, and the second mode of operation includes operating the engine with a stoichiometric air-fuel ratio.

2. A method according to claim 1, wherein the first set of conditions include exhaust gases at a relatively low exhaust gas temperature.

3. A method according to claim 2, wherein the exhaust gas temperature is in the range of 200 to 400 degrees Celsius.

4. A method according to any one of claims 1 to 3, wherein the second set of conditions include exhaust gases at a relatively high exhaust gas temperature.

5. A method according to claim 4, wherein the exhaust gas temperature is greater than 200 degrees Celsius.

6. A method according to claim 5, wherein the exhaust gas temperature is greater than 400 degrees Celsius.

7. A method according to any one of claims 2 to 6, including measuring the exhaust gas temperature at the first catalyst converter.

8. A method according to claim 1, including controlling the temperature of the exhaust gas temperature of the engine by appropriate operation of the engine to ensure effective operation of the first catalyst converter under the first mode of operation.

9. A method according to claim 8, including controlling the exhaust gas temperature to be in the range of 200 to 400 degrees Celsius.

10. A method according to claim 1,8 or 9, including controlling the temperature of the exhaust gas temperature of the engine by appropriate operation of the engine to ensure effective operation of the first catalyst converter under the second mode of operation.

11. A method according to claim 10, including controlling the exhaust gas temperature to be greater than approximately 400 degrees Celsius.

12. A method according to any one of the preceding claims, wherein the operation of the engine is controlled during the first mode so as to generate the exhaust gas emissions having characteristics that can support acceptable levels of NOx conversion within the first catalyst converter.

13. A method according to any one of the preceding claims, wherein the first catalyst converter includes a combination of Pt, Rh and Ba elements.

14. A method according to any one of claims 1 to 13, wherein the first catalyst converter includes a combination of Pd, Rh and Ba elements.

15. A method according to claim 13, wherein the proportion of Pt is greater than for a typical three way catalyst.

16. A method according to claim 14, wherein the ratio of Pt to Rh is 10:1.

17. A method according to claim 13, 15 or 16, wherein the proportion of Ba in the first catalyst converter is relatively low as compared to the proportions of Pt and Rh.

18. A method according to any one of the preceding claims, including controlling the operation of the engine during the first mode so as to promote a selective catalyst NOx reduction process at the first catalytic converter.

19. A method according to claim 18, including controlling the operation of the engine during the second mode so as to promote high NOx conversion efficiency levels within the first catalytic converter.

20. A method according to claim 19, including operating the engine in the first mode when the sensed temperature is between 200 to 400 degrees Celsius, and operating the engine in the second mode when the sensed temperature is greater than 400 degrees Celsius.

21. A method according to any one of the preceding claims, wherein the first catalyst converter is provided in the exhaust system at a position sufficiently downstream of the engine such that there is some cooling of the exhaust gas prior to the exhaust gas entering the first catalyst converter.

22. A method according to claim 21, wherein the catalyst means includes a second catalyst converter provided in a close coupled configuration with the engine for the purpose of oxidising hydrocarbon and carbon monoxide emissions in the exhaust gas.

23. A method according to any one of the preceding claims, wherein the first catalyst converter is a three way catalyst.

24. A method according to any one of the preceding claims, wherein the engine is directed injected.

25. A method according to claim 24, wherein the engine has a two fluid fuel injection system.

26. An engine exhaust system for treating NOx emissions in the exhaust gas of an internal combustion engine, including catalyst means having at least a first catalyst converter capable of treating NOx, wherein the engine exhaust system is adapted to treat the Nox emissions when the engine is operated in a first mode to promote a first set of conditions and in a second mode to promote a second set of conditions, the first mode of operation including operating the engine with a lean air-fuel ratio, and the second mode of operation including operating the engine with a stoichiometric air-fuel ratio.

27. An engine exhaust system according to claim 26, wherein the first catalyst converter includes a combination of Pt, Rh and Ba elements.

28. An engine operating system according to claim 26, wherein the first catalyst converter includes a combination of Pd, Rh and Ba elements.

29. An engine exhaust system according to claim 27, wherein the proportion of Pt is greater than for a typical three way catalyst.

30. An engine exhaust system according to claim 29, wherein the ratio of Pt to Rh is 10:1.

31. An engine exhaust system according to claim 27, 29 or 30, wherein the proportion of Ba in the first catalyst converter is relatively low as compared to the proportions of Pt and Rh.

32. An engine exhaust system according to any one of claims 26 to 30, including a temperature sensing device provided in the exhaust system of the engine for measuring the exhaust gas temperature.

33. An engine exhaust system according to claim 32, wherein the temperature sensing device is located at the first catalyst converter.

34. An engine exhaust system according to claim 32 or 33, wherein the engine is operated in the first mode when the sensed temperature is between 200 to 400 degrees Celsius, and the engine is operated in the second mode when the sensed temperature is greater than 400 degrees Celsius.

35. An engine exhaust system according to any one of claims 26 to 34, wherein the first catalyst converter is provided in the exhaust system at a position sufficiently downstream of the engine such that there is some cooling of the exhaust gas prior to the exhaust gas entering the first catalyst converter.

36. A method according to claim 35, wherein the catalyst means includes a second catalyst converter provided in a close coupled configuration with the engine for the purpose of oxidising hydrocarbon and carbon monoxide emissions in the exhaust gas.

37. A method according to any one of claims 26 to 36, wherein the first catalyst converter is a three way catalyst.

38. An electronic control unit for controlling an internal combustion engine having catalyst means including at least a first catalyst converter capable of treating NOx, the electronic control unit operating the engine in a first mode to promote a first set of conditions and in a second mode to promote a second set of conditions, wherein the first mode of operation includes operating the engine with a lean air-fuel ratio, and the second mode of operation includes operating the engine with a stoichiometric air-fuel ratio to thereby treat NOx emissions in the exhaust gas of the engine.

39. An internal combustion engine for use with an exhaust treatment system having reversible NOx adsorbent capability, said engine having a fuel injection system which facilitates operation of said engine with a plurality of air fuel ratios in a range between lean and rich and said engine having an electronic controller for controlling operation of said engine and for selecting between said air fuel ratios

wherein said selection is not directly dependent on the amount of NOx stored or calculated to be stored in said exhaust treatment system.

40. An internal combustion engine as claimed in claim 39 wherein said selection between said air fuel ratios by said electronic controller is independent of the amount of NOx stored or calculated to be stored in said exhaust treatment system.

41. An internal combustion engine as claimed in claim 39 or claim 40 wherein at least some of the NOx stored in said exhaust treatment system is purged therefrom in response to operation of the engine with a substantially stoichiometric or rich air fuel ratio.

42. An internal combustion engine as claimed in claim 39 or claim 40 wherein at least some of the NOx stored in said exhaust treatment system is purged therefrom in response to operation of the engine with a stoichiometric air fuel ratio.

43. An internal combustion engine as claimed in any one of claims 39 to 42 wherein said selection is at least in part dependent on engine load demand.

44. An internal combustion engine as claimed in any one of claims 39 to 41 wherein exhaust emissions generated by said engine at a substantially stoichiometric or rich air fuel ratio and transmitted to said exhaust treatment system operate to purge NOx stored in said exhaust treatment system.

45. An internal combustion engine as claimed in any one of claims 39 to 41 wherein exhaust emissions generated by said engine at a stoichiometric air fuel ratio and transmitted to said exhaust treatment system operate to purge NOx stored in said exhaust treatment system.

46. An internal combustion engine as claimed in claim 44 wherein exhaust emissions generated by said engine at a substantially stoichiometric air fuel ratio and transmitted to said exhaust treatment system operate to purge NOx stored in said exhaust treatment system over a Euro 3 drive cycle.

47. An internal combustion engine as claimed in any one of claims 44 or 46 wherein exhaust emissions generated by said engine at a substantially stoichiometric air fuel ratio and transmitted to said exhaust treatment system operate to purge NOx stored in said exhaust treatment system over a Euro 4 drive cycle.

48. An internal combustion engine as claimed in any one of claims 39 to 47 wherein the amount of NOx emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than four times the Euro III requirement.

49. An internal combustion engine as claimed in claim 48 wherein the amount of NOx emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than three times the Euro III requirement.

50. An internal combustion engine as claimed in any one of claims 46 to 49 wherein the amount of carbon monoxide emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than three times the Euro III requirement.

51. An internal combustion engine as claimed in any one of claims 46 to 50 wherein the amount of hydrocarbons emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than ten times the Euro III requirement.

52. An internal combustion engine as claimed in any one of claims 39 to 51 wherein said engine is a direct injection gasoline engine.

53. An internal combustion engine as claimed in any one of claims 39 to 52 wherein said engine is a dual fluid direct injection engine.

54. An internal combustion engine and exhaust treatment system for a vehicle, said exhaust treatment system having reversible NOx adsorbent capability, said engine having a fuel injection system which facilitates operation of said engine with a plurality of air fuel ratios in a range between lean and rich and said engine having an electronic controller for controlling operation of said engine and for selecting between said air fuel ratios wherein the amount of NOx emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than four times the Euro III requirement whereby said exhaust treatment system has emissions of NOx, carbon monoxide and hydrocarbons less than said Euro III requirement over said Euro III drive cycle.

55. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 54 wherein said selection of air fuel ratio by said electronic controller is independent of the amount of NOx stored in said exhaust treatment system.

56. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 54 wherein exhaust emissions generated by said engine at a substantially stoichiometric air fuel ratio and transmitted to said exhaust treatment system operate to purge NOx stored in said exhaust treatment system during said Euro III drive cycle.

57. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 54 to 56 wherein the amount of hydrocarbons emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than ten times the Euro III requirement.

58. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 54 to 57 wherein the amount of carbon monoxide emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than three times the Euro III requirement.

59. An internal combustion engine and exhaust treatment system as claimed in any one of claims 54 to 58 wherein selection of a substantially stoichiometric air fuel ratio is dependent at least in part on driver demand.

60. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 54 to 59 wherein for substantially all of the lean air fuel ratios, said electronic controller operates said engine with EGR levels of 25% by mass or greater.

61. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 54 to 60 wherein said engine is a direct injection engine.

62. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 54 to 61 wherein said engine is a duel fluid direct injection engine.

63. An internal combustion engine for use with an exhaust treatment system having reversible NOx adsorbent capability, said engine having a fuel injection system which facilitates operation of said engine with a plurality of air fuel ratios in a range between lean and substantially stoichiometric and said engine having an electronic controller for controlling operation of said engine and for selecting said substantially stoichiometric air fuel ratio to purge NOx stored in said exhaust treatment system.

64. An internal combustion engine as claimed in claim 63 wherein exhaust emissions generated by said engine when operated with a substantially

stoichiometric air fuel ratio and transmitted to said exhaust treatment system operate to purge NOx stored in said exhaust treatment system during a Euro III drive cycle.

65. An internal combustion engine as claimed in any one of claims 63 or 64 wherein exhaust emissions generated by said engine at a substantially stoichiometric air fuel ratio and transmitted to said exhaust treatment system operate to purge NOx stored in said exhaust treatment system during a Euro IV drive cycle.

66. An internal combustion engine as claimed in any one of claims 63 to 65 wherein the selection of said substantially stoichiometric air fuel ratio is effected independent of the amount of NOx stored or calculated to be stored in said exhaust treatment system.

67. An internal combustion engine as claimed in any one of claims 63 to 66 wherein the amount of NOx emitted by said engine to said exhaust treatment system during said Euro III drive cycle are no more than four times the Euro III requirement.

68. An internal combustion engine as claimed in any one of claims 63 to 66 wherein the amount of NOx emitted by said engine to said exhaust treatment system during said Euro III drive cycle are no more than three times the Euro III requirement.

69. An internal combustion engine as claimed in any one of claims 63 to 68 wherein the amount of carbon monoxide emitted by said engine to said exhaust treatment system during said Euro III drive cycle is no more than three times the Euro III requirement.

70. An internal combustion engine as claimed in any one of claims 63 to 69 wherein the amount of hydrocarbons emitted by said engine to said exhaust

treatment system during said Euro III drive cycle is no more than ten times the Euro III requirement.

71. An internal combustion engine as claimed in any one of claims 63 to 70 wherein for substantially all of the lean air fuel ratios, said engine operates with EGR levels of 25% by mass or greater.

72. An internal combustion engine as claimed in any one of claims 63 to 71 wherein said electronic controller selects said stoichiometric air fuel ratio at least as a cumulative measure of emissions transmitted to the exhaust treatment system.

73. An internal combustion engine as claimed in claim 72 wherein said cumulative measure is determined from engine operating conditions over a predetermined period of time.

74. An internal combustion engine as claimed in claim 73 wherein said operating conditions is at least one of engine speed and / or engine load.

75. An internal combustion engine as claimed in any one of claims 73 or 74 wherein said predetermined period of time is elapsed time since said engine operated with a stoichiometric air fuel ratio.

76. An internal combustion engine as claimed in claim 75 wherein said predetermined period of time is elapsed time since said engine operate with a stoichiometric air fuel ratio for a period sufficient to substantially purge said catalyst of stored NOx.

77. An internal combustion engine as claimed in any one of claim 72 to 76 wherein said cumulative measure is an estimate based on emission levels emitted at each selected air fuel ratio.

78. An internal combustion engine as claimed in any one of claims 72 to 77 wherein said cumulative measure is based on the amount of time said engine was operated at each selected air fuel ratio.

79. An internal combustion engine as claimed in any one of claims 72 to 78 wherein said stoichiometric air fuel ratio is selected for a period sufficient to regenerate said exhaust treatment system from stored NOx and wherein subsequent to said period sufficient to regenerate said exhaust treatment system said electronic controller selects an air fuel ratio dependent on prevailing engine conditions.

80. An internal combustion engine as claimed in any one of claims 63 to 71 wherein said electronic controller selects said stoichiometric air fuel ratio in response to a sensing means operatively arranged with respect to the exhaust treatment system which is able to provide an indication on the amount of NOx stored therein.

81. An internal combustion engine as claimed in claim 80 wherein said electronic controller only selects said stoichiometric air fuel ratio in response to a signal from said sensing means that purging of NOx from the exhaust treatment system is required.

82. An internal combustion engine as claimed in claims 80 or 81 wherein said selection of said stoichiometric air fuel ratio by the electronic controller to effect purging of NOx from the exhaust treatment system is also dependent on the volume of a catalyst in the exhaust treatment system.

83. An internal combustion engine as claimed in any one of claims 63 to 82 wherein said engine is a direct injection engine.

84. An internal combustion engine as claimed in any one of claims 63 to 83 wherein said engine is a dual fluid direct injection engine.

85. An internal combustion engine and exhaust treatment system for use in a vehicle, said exhaust treatment system comprising at least one catalyst having three way conversion capability and NOx storage capability, wherein the amount of NOx emitted by said engine to said exhaust treatment system over a Euro III drive cycle is no more than four times the Euro III requirement whereby said exhaust treatment system has emissions of NOx, carbon monoxide and hydrocarbons less than said Euro III requirement over said Euro III drive cycle, and the volume of the catalyst is less than 150% of the swept volume of said engine.

86. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 85 wherein said catalyst has substantially two zones, a first of which has said three way conversion capability and a second of which has at least said NOx storage capability

87. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 86 wherein said second zone of said catalyst has three way conversion capability in addition to said NOx storage capability.

88. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 86 wherein said first zone is located so as to received exhaust emissions from said engine before said second zone.

89. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 85 to 88 wherein said exhaust treatment system has a single canister for locating said at least one catalyst, said canister located remotely from an exhaust port of said engine and not within an engine compartment in which the engine is installed.

90. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 89 wherein single canister is located in an underbody location and has dimensions of less than 150% of the swept volume of the engine.

91. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 85 to 90 wherein exhaust emissions generated by said engine when operated with a substantially stoichiometric air fuel ratio operate to purge NOx stored in said exhaust treatment system during said Euro III drive cycle.

92. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 85 to 91 wherein the amount of carbon monoxide emitted by said engine to said exhaust treatment system over said Euro III drive cycle is no more than three times the Euro III requirement.

93. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 85 to 92 wherein the amount of hydrocarbons emitted by said engine to said exhaust treatment system over said Euro III drive cycle is no more than ten times the Euro III requirement.

94. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 85 to 93 wherein the amount of NOx emitted by said engine to said exhaust treatment system over said Euro III drive cycle is no more than three times the Euro III requirement.

95. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 85 to 94 wherein for substantially all of the lean air fuel ratios, said engine operates with EGR levels of 25% by mass or greater.

96. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 85 to 95 wherein in operation said catalyst is heated by a light off strategy.

97. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 96 wherein said light off strategy comprises late combustion of fuel whilst an exhaust port of said engine is open whereby said catalyst receives exhaust emissions of an elevated temperature.

98. An internal combustion engine and exhaust treatment system for a vehicle as claimed in claim 97 wherein late combustion of fuel comprises a quantity of fuel in addition to a quantity required for operation of said engine independent of said light off strategy.

99. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 85 to 98 wherein said engine is a direct injection engine.

100. An internal combustion engine and exhaust treatment system for a vehicle as claimed in any one of claims 85 to 99 wherein said engine is a dual fluid direct injection engine.

Fig 1.

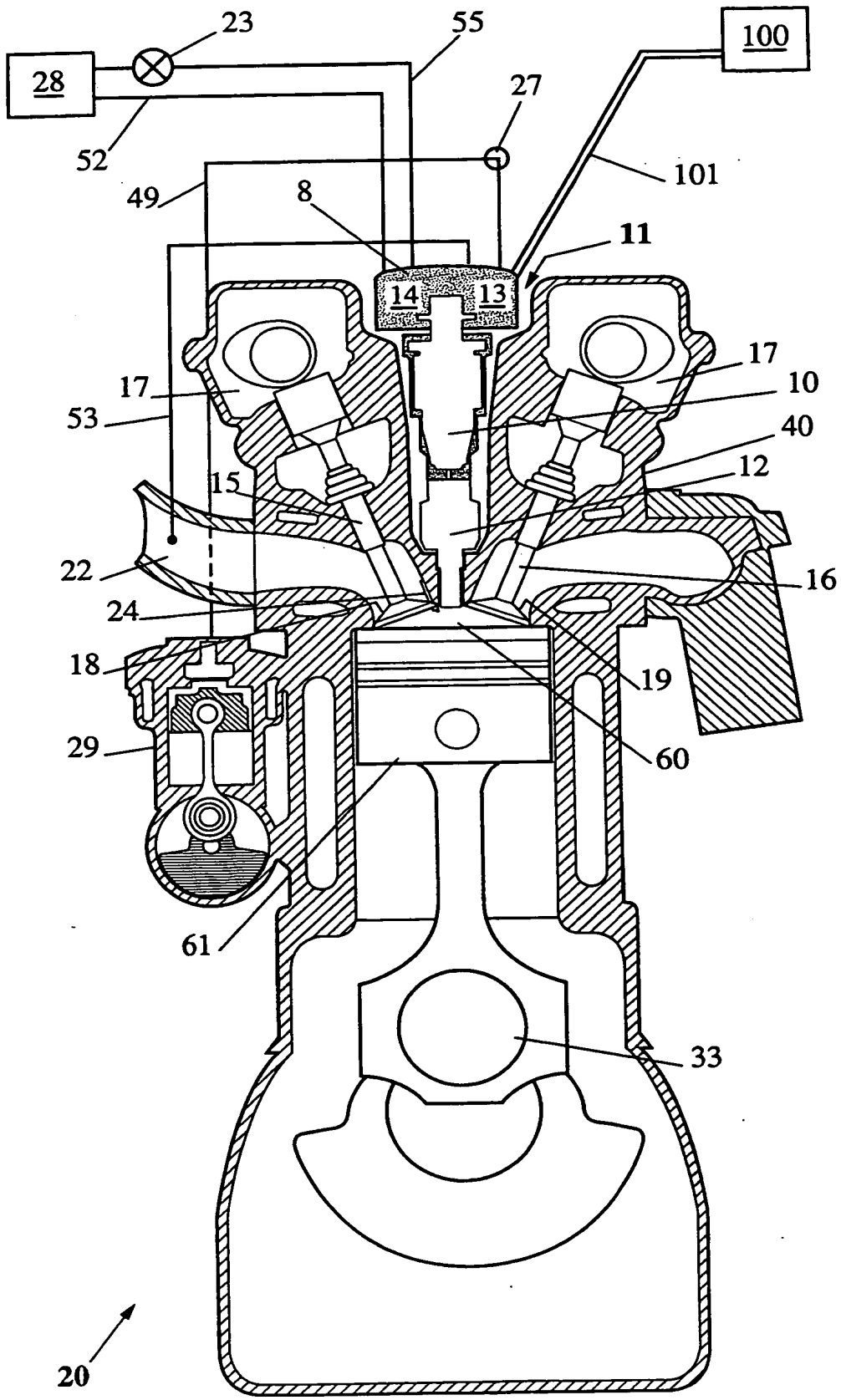
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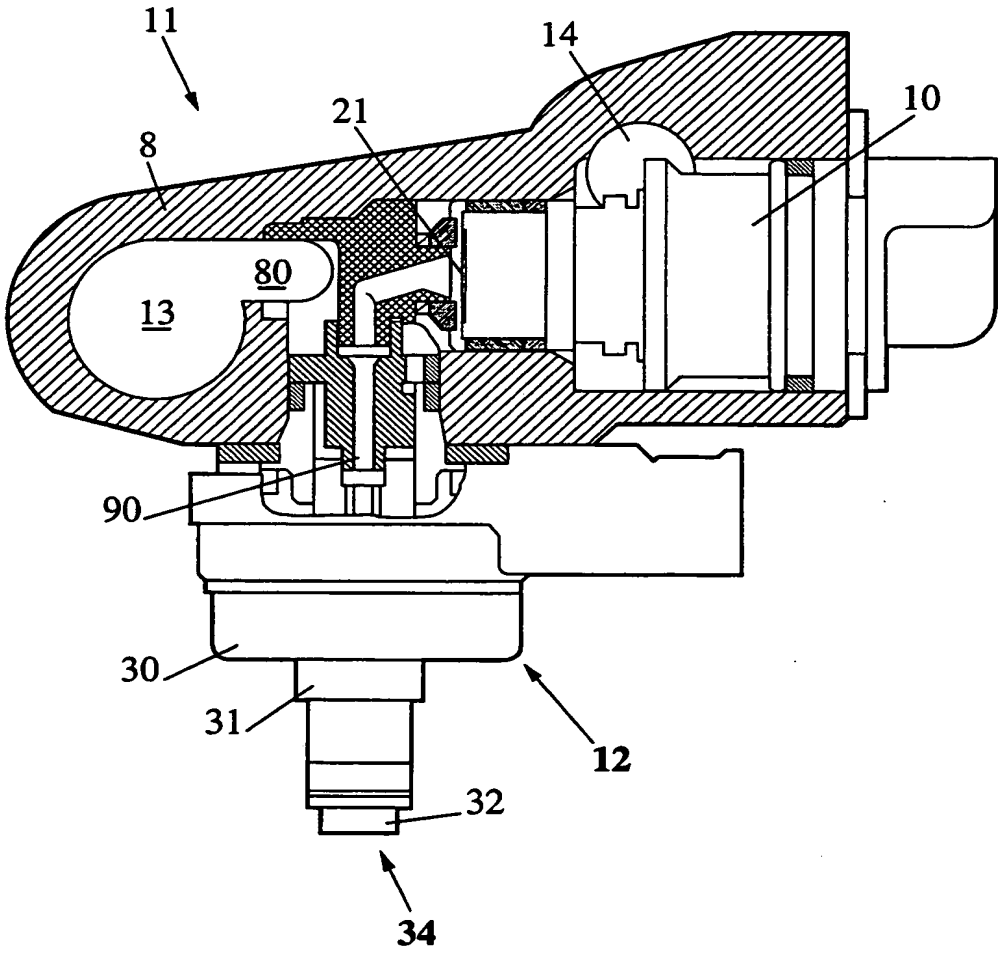
Fig 2.



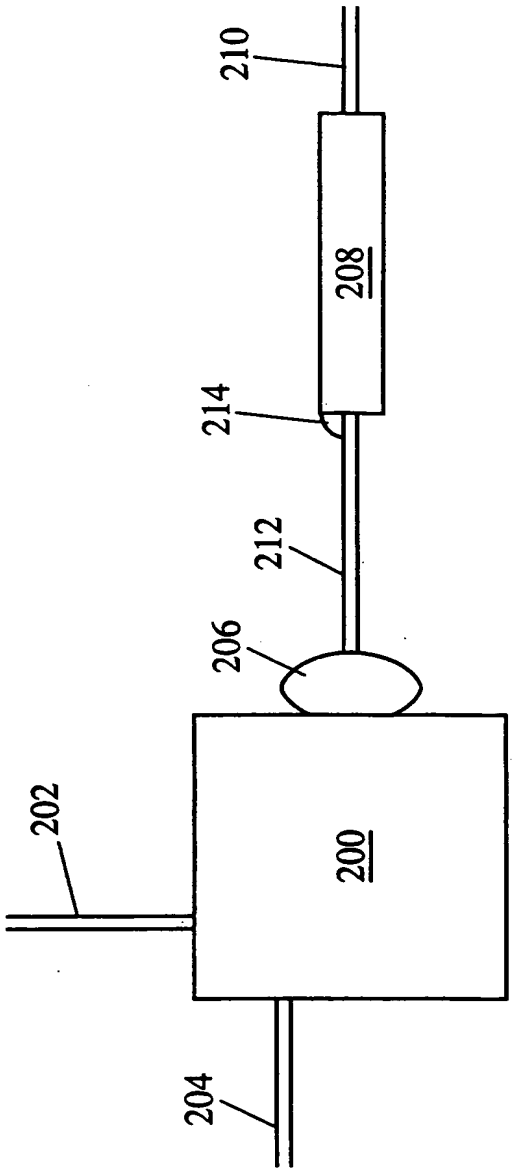


Fig 3.

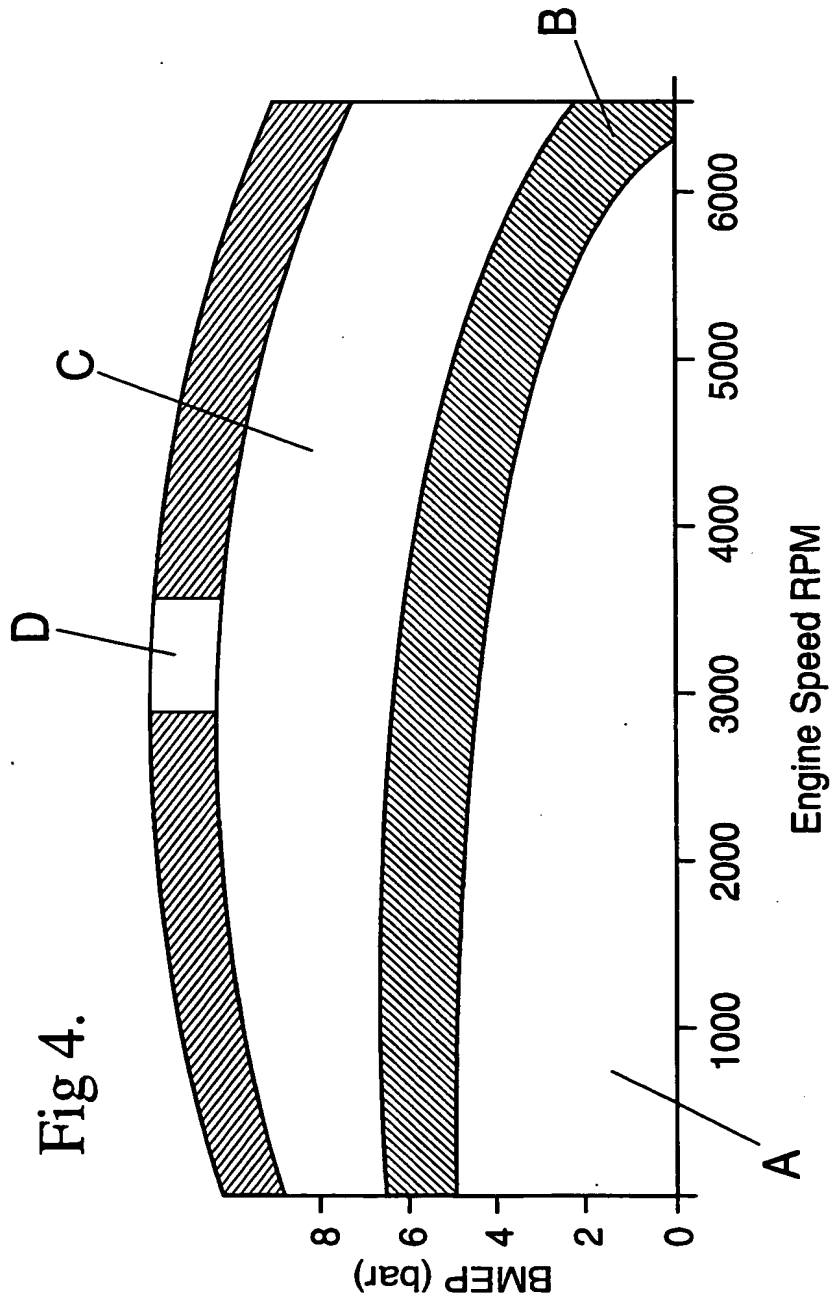
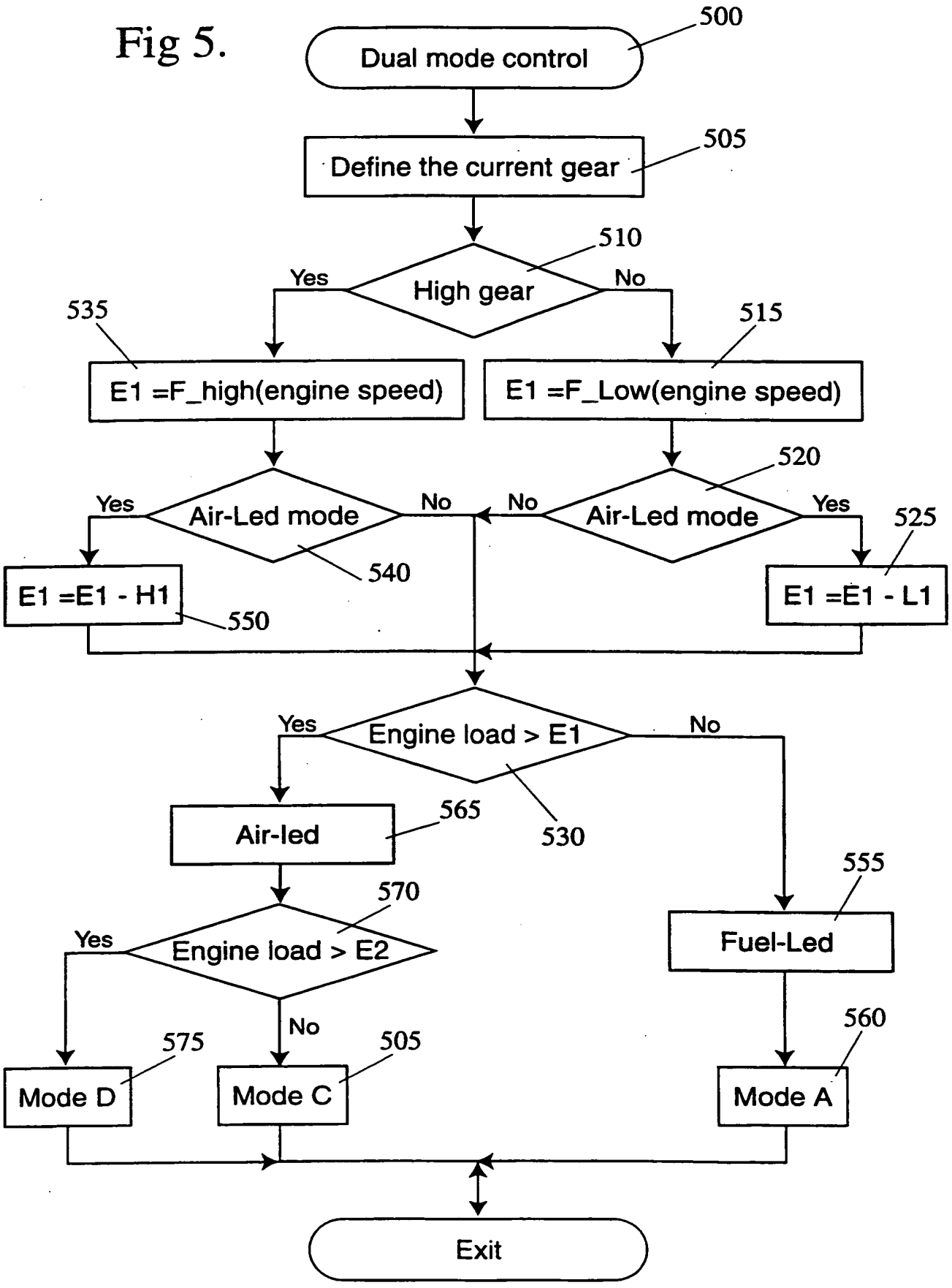

B
C
D
A
0
2
4
6
8
BMEP (bar)
1000
2000
3000
4000
5000
6000
Engine Speed RPM

Fig 4.

Fig 5.


500
Dual mode control
505
Define the current gear
510
High gear
Yes
No
535
E1 =F_high(engine speed)
515
E1 =F_Low(engine speed)
520
Air-Led mode
Yes
No
540
Air-Led mode
No
Yes
525
E1 =E1 - H1
550
E1 =E1 - L1
Engine load > E1
Yes
No
530
Air-led
565
555
570
Engine load > E2
Yes
Fuel-Led
No
560
575
505
Mode D
Mode C
Mode A
Exit